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A LOGISTICS SUPPORT COST ANALYSIS OF THE ADVANCED AERIAL REFUELING BOOM

THESIS

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Preface

This thesis describes research which was directed toward obtaining an initial logistics support cost estimate for Douglas Aircraft Company's proposed Advanced Aerial Refueling Boom (AARB). The project consisted of making a comparative logistics support cost analysis between the AARB and the existing KC-135 boom system. The research was performed during March through June 1976, a time when relatively little technical data on the AARB was available. This research project was suggested and sponsored by the Advanced Tanker/Cargo Aircraft System Program Office (ATCA SPO).

We would like to express our appreciation to Dr. N. Keith Womer, our faculty advisor, for his support and advice during the course of this research effort; and to Colonel Ronald A. Luhks, our faculty reader, for his many helpful suggestions and assistance in editing the manuscript. Thanks go to Captain Henry G. Hamby, III, who suggested the project and who served as our primary contact in the ATCA SPO.

There were many others who willingly supported our research effort and who contributed their knowledge and suggestions. Thanks to Captain Paul O. Weaver, AFALD/XRSA, whose intimate knowledge of the LSC Model was invaluable; he provided many helpful consultations. Thanks go to Colonel William Bowden, Oklahoma City Air Logistics Center/MMC (the KC-135 System Manager) and the many members of his staff, particularly Mrs. Margaret Marquartz, who unselfishly and enthusiastically

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Richard T. Jeffreys

Carver L. Sears

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Abstract

Under an Air Force contract, Douglas Aircraft Company is developing an Advanced Aerial Refueling Boom (AARB) for the Advanced Tanker/Cargo Aircraft System Program Office (ATCA SPO). The purpose of the AARB development program is to demonstrate that an advanced technology boom system, which will eliminate some of the limitations of the existing KC-135 boom, can be designed and successfully flown. To date, development of the AARB has been mainly oriented toward performance--meeting the design requirements. The ATCA SPO now desires to examine the costs of supporting the proposed design, if it is produced.

This thesis is directed toward identifying the differential logistics support costs of the AARB. The Boom Model, a tailored version of the Air Force Logistics Command Logistics Support Cost (LSC) Model, is used to develop the logistics support cost figure of merit for the proposed AARB. The Boom Model is also used to develop a similar figure of merit for the existing KC-135 boom. The values for variables used in the KC-135 boom analysis are obtained from existing Air Force maintenance data collection systems. A methodology for extracting data from these systems is given. Because of the uncertainties associated with early, initial estimates for the AARB, sensitivity analyses are performed on selected variables. Conclusions and recommendations pertaining to both the AARB and KC-135 boom analyses and the LSC Model are given.

A LOGISTICS SUPPORT COST ANALYSIS OF THE ADVANCED AERIAL REFUELING BOOM

I. Introduction

This chapter presents the research problem associated with the thesis. It describes the background and rationale behind the current development of an Advanced Aerial Refueling Boom. It describes the methodology developed to perform the logistics support cost analysis which was the central theme of this research effort. The final section of this chapter describes the organization and relationships of the following five chapters. Technical explanations and descriptions are more fully developed in later chapters.

Background

The changing world political situation has resulted in increasingly independent action on the part of allies and friendly nations and a lessening of the ability of the United States to rely on overseas airbases. The Arab-Israeli War of 1973 highlighted the threat of the denial of base rights by allies and friendly nations in the event of a conflict in which the host nations may have mixed loyalties or interests.

The United States has perceived a need to enhance its ability to extend quick reaction forces to any area of the world without dependence on enroute overseas bases and overflight rights. The Advanced Tanker/Cargo Aircraft (ATCA) will make this possible by providing the capability for refueling

large transport aircraft, like the C-5A and C-141, at extremely long ranges. It will also be able to support long range deployments of fighter units while providing concurrent airlift of support equipment and personnel. The capacity required for U.S. based strategic airlift or tactical mobility missions exceeds the capabilities of the current KC-135 tanker. Furthermore, the size of the fuel off-loads required and the great ranges of these missions would require KC-135 tankers in such numbers as to make operations impractical (71:17).

Direct procurement of an off-the-shelf wide-bodied transport aircraft is planned for the ATCA. This approach will take advantage of the sunk development costs of an already proven system. Development funds will be limited to subsystems such as an advanced boom and a multipoint refueling system. The multipoint system will allow more than one fighter to refuel at the same time.

The need for an advanced boom. Although the KC-135 tanker and its aerial refueling system have served well in their present roles, several limitations of the boom have been emphasized in recent years by problems experienced in refueling large new receiver aircraft such as the C-5A. The most important limitations of the KC-135 boom are listed here (2:1):

1. Inadequate control of boom movement and position throughout the range specified in MIL-F-38363B(USAF) (59).

2. Limited separation between the tanker and the receiver. This is a particular problem when refueling the C-5A and the E-4A because of the large bow waves of these aircraft which causes interference with the normal aerodynamic forces acting on the tanker.

3. Limited fuel flow rate during fuel off load to receiver aircraft causing excessive time to be required for refueling large aircraft. The maximum fuel flow rate for the KC-135 boom while refueling is 1200 gallons per minute.

4. Normal, automatic disconnect capability is dependent upon proper operation of the electrical and hydraulic systems in the receiver aircraft.

These limitations make refueling the C-5A, for example, very difficult. The bow wave associated with very large aircraft makes the insertion of the nozzle difficult due to insufficient control authority. Also, this lack of control capability results in the buildup of unbalanced aerodynamic forces on the boom while in contact with receiver aircraft. These unbalanced forces, potentially causing binding of the nozzle in the refueling receptacle, may make extraction of the nozzle difficult and hazardous.

Aerial refueling is an extremely demanding phase of flight. Safety and fuel economy dictate that the time in this phase be reduced to the minimum. When refueling with the KC-135, it is not uncommon for large offloads (80,000 to 120,000 pounds of fuel) to require in excess of thirty minutes. Under the long range airlift concept being planned,

offloads could be more than twice this size. For this reason, the fuel flow capability of the KC-135 boom system is inadequate for the mission of the ATCA.

Disconnect problems with the KC-135 boom have existed for years and not only with the large receivers. The present boom disconnect system is felt to be inadequate because its normal, automatic disconnect capability is dependent upon proper operation of the electrical and hydraulic parts of the aerial refueling system in the receiver aircraft. Dependence upon a completed electrical circuit with the electrical system in the receiver aircraft has meant frequent loss of disconnect capability with the resulting need for a "brute force" disconnect. This type of disconnect can be dangerous, as a small aircraft can be pulled into contact with the rigid, non-telescoping structure of the boom.

The Advanced Aerial Refueling Boom

In order to remedy the deficiencies of the KC-135 boom and provide aerial refueling capabilities commensurate with the mission of the ATCA, an Advanced Aerial Refueling Boom (AARB) is being developed by the Douglas Aircraft Company, a subsidiary of McDonnell Douglas Corporation. The AARB may also be considered for installation on the KC-135 fleet at some point in the future (71:18).

Although the AARB was conceived for the ATCA, it may or may not eventually become a part of the ATCA. The AARB incorporates several design concepts which have not yet been

proven and there is a considerable amount of risk still associated with the program at the time of this thesis. The ATCA boom, as presently planned, will be furnished by the ATCA contractor; therefore, whichever aircraft is selected for the ATCA may largely determine whether the Douglas AARB is used. The ATCA System Program Office, however, is interested in several design concepts proposed for the AARB and a test program has been scheduled for late 1976 and 1977 to demonstrate the feasibility of the AARB design. One prototype AARB will be built and installed, for this test phase, on a KC-135 airframe.

AARB design features. According to Douglas (3:8), the AARB will provide improved capabilities, while overcoming the major limitations of the current boom, through some of the following design features.

1. The AARB will provide a larger refueling envelope which equals or exceeds that required by MIL-F-38363B(USAF). The KC-135 boom falls far short of most of the lower outer portion of the required envelope (2:4). This larger envelope means that the limits of movement of the receiver, relative to the tanker, will be greater than is possible with the KC-135 boom thereby lessening the need for disconnect.

2. The AARB will be more controllable because it will have: (a) an improved boom pivot system thereby lessening the aerodynamic forces which must be counteracted by the flight control surfaces and (b) an improved control surface configuration.

3. The AARB will incorporate an integrated fly-by-wire control system. In addition to reducing weight and allowing improvements in boom controllability, the fly-by-wire system will permit automatic trimming of boom flight control surfaces while connected with the receiver. This Automatic Load Alleviation System will prevent the buildup of unbalanced aerodynamic loads which could cause the boom to whip into the receiver upon disconnect or cause the nozzle to bind in the receptacle.

4. The AARB will provide an additional five feet of vertical separation between the tanker and the receiver. This is especially important for large receivers because it will reduce the effects of the receiver bow wave on the tanker aircraft.

5. The AARB and the Advanced Aerial Refueling Nozzle (AARN) will allow an increased fuel flow rate during fuel offload. This will substantially reduce the time required to refuel the large-capacity receivers.

6. The AARB/AARN will incorporate a redundant disconnect capability that is not dependent upon operation of the hydraulic and electrical systems of the receiver. This capability will substantially reduce the number of disconnect problems.

Given that there are limitations associated with the existing KC-135 boom system and that preliminary designs for an AARB system which could correct these deficiencies have

been completed, it is now desired to investigate some operating and support cost implications of acquiring a new system such as the AARB.

Life Cycle Costs

System development has occurred, in the past, with little concern for the life cycle costs of the equipment being developed. The concern of both the developers and the services has been more typically for the initial development cost of the system. As stated by Dover and Oswald (32:1-2),

> . . . RDT&E and investment costs, which occur only once in the life cycle of a weapon system, may represent only a small portion of the total ownership cost. A more submerged category of operational costs continues to recur throughout the life of the system. This category includes the annual operating and support costs associated with corrective and preventive maintenance, . . . installation and checkout, transportation, documentation . . . .

As has been highlighted frequently in recent literature, the operation and support costs of a system over its useful life can actually exceed the acquisition costs by several times.

Lack of attention to support cost implications of equipment designs has been a major contributor to ballooning life cycle costs. The DoD Cost Analysis Improvement Group (63:2) points out that each year the cost to maintain existing combat forces increases, and unless some action is taken to reduce the out-year operating and support costs, the resources available to develop and acquire new weapon systems will become proportionately smaller. As a result, operating and support cost estimates are required on weapon systems

that are reviewed by the Defense Systems Acquisition Review Council.

Because of increased awareness in these areas, the Air Force is now: (1) estimating the operation and support costs of proposed systems and comparing them with current systems, (2) focusing upon field reliability and comprehensive test programs rather than planned reliability, (3) trying new contracting concepts including reliability warranties and incentives, (4) considering design tradeoffs to reduce life cycle costs, and (5) investigating logistics support alternatives and their impacts upon costs (24:2).

Statement of the Research Problem

The development of the AARB to date has been mainly oriented toward performance--meeting certain capabilities through advanced design concepts. However, all cost considerations have not been ignored. Several aspects of the AARB design are related directly to improving reliability and ease of maintenance. It is now desired to examine some of the life cycle costs of supporting the proposed design.

This research effort was suggested by the ATCA System Program Office (SPO) as the first step in a continuing logistics support analysis. It was intended that a logistics support cost figure of merit for the AARB be developed using the Air Force Logistics Command Logistics Support Cost (AFLC LSC) Model. This estimate was to be compared with a similar logistics support cost figure of merit to be developed for the KC-135 boom system. The results of the comparison were expected to

highlight differences in logistics support costs which could be related to design differences between the two systems. It was also desired to identify those particular design parameters or components which may add significantly to the logistics support costs so that alternative actions could be considered early in the development process.

The analysis contained herein, based as it is on preliminary design information, is merely the first step of a comprehensive logistics support cost analysis. If the AARB is selected for the ATCA, and if a more complete logistics support cost analysis is desired, then periodic updates of these estimates will be required as the AARB design evolves.

Significance of the Research

The primary significance of this research effort lies in the methodology developed for estimating the logistics support costs of an existing Air Force weapon system so that comparison is possible with a proposed system. The LSC Model was specified for use by the ATCA SPO for this project. The model is well known and has been used in several programs to analyze and compare proposed designs. It is also used for tracking of logistic support cost estimates as program definition proceeds. The methodology developed for this research and the modifications made to the LSC Model will be available for further use for this, and other, programs. Others using the LSC Model, especially for analyzing existing systems, may also find the techniques developed here useful.

The results of the AARB component breakdown and logistics support cost analyses will be available for use as a baseline in evaluating the development of the AARB, if that program should be continued beyond the feasibility demonstration now planned.

Assumptions

Several assumptions were necessary in order to limit the research project to a manageable size while still producing some useful and meaningful results for the SPO. The results are limited by the assumptions upon which the study was based.

1. It was assumed that the most recent KC-135 logistics support cost data represented the best data base for the LSC Model variables. Since it would be difficult to anticipate future failure trends in an aging system, no attempt was made to do so. The current reduced level of flying was felt to be the best predictor of future activity. In order to avoid continuous changes to the data as more recent data became available, it was decided that it was best to proceed with the analysis using the most current data available at the end of April 1976.

2. All existing KC-135 booms were assumed to be identical. Likewise, the usage of the weapon system and costs of operation were assumed to occur uniformly across the fleet.

3. Both the KC-135 boom and the AARB were assumed to be installed on the KC-135 aircraft for purposes of this

study. The LSC Model equations require weapon system data as well as system and component level data. This assumption was necessary in order to isolate any logistics support cost differences to the boom systems themselves rather than to any differences which might be the result of installation on different aircraft.

Also, no attempt was made to develop logistics support cost figures of merit for the KC-135 boom and the proposed AARB as an integral part of the ATCA. To develop such estimates would have required a complete logistics support cost analysis of the ATCA. Such an exercise would have been well beyond the scope of this research study.

4. The analysis was conducted under the assumption that the AARB, as then conceived, was a feasible design. Unproven and incompletely defined components were included, as proposed, assuming that they would become part of the final design configuration.

5. It was assumed that the time value of money was not important to the comparison. Since the two systems were to be compared over the same period of time, the effects of the time value of money were assumed to be the same for both and could therefore be ignored. To attempt to account for such effects would unnecessarily complicate the model and would tend to mask the design differences which are the focus of this type of model.

Limitations

This study is limited by the assumptions listed above. In addition, there are several limitations listed in Chapter II which are the result of the assumptions and characteristics inherent in the LSC Model. It is essential that these assumptions be made clear so that the results of studies like this one, which are based on mathematical models and tightly constraining assumptions, are not applied to situations for which they are not appropriate.

Methodology

This section presents a general overview of the methodology that was used during this research study. The specific aspects of the LSC Model and its adaptation for these analyses, the KC-135 boom analysis, and the AARB analysis appear in Chapters II, III, and IV respectively.

The initial step in this research project was a thorough study of the KC-135 boom system. All major parts, components and assemblies were identified by function and location. Next, a list of components was selected which was expected to represent over 80 percent of the logistics support costs of all boom components.

In order to complete the parts breakdown, and later to gather cost information on the components selected, it was necessary to construct a cross reference between Work Unit Codes (WUC) and National Stock Numbers (NSN). Base level work is always reported by WUC, while parts and costs are managed at depot level by reference to the appropriate

NSN. There being no authoritative cross reference between WUCs and the inclusive national stock numbers, the task of consistently matching the base and depot level costs was difficult.

The data search consisted of locating sources for the input elements required for the model. Some of this information was not available in the forms required and several model changes were decided upon which were meant to allow the use of existing data sources. This will be more fully explained in Chapter II. Some model changes were also made so that the model would more nearly reflect particular aspects of the system being studied--an aircraft refueling boom system. A modified LSC Model, called the Boom Model, was derived. It is described in detail in Chapter II.

The AARB was studied next. The only reference materials available were the series of Douglas Aircraft Company reports on the preliminary AARB design (3,4,5,6). These were supplemented by discussions with knowledgeable persons in the ATCA SPO and other engineering personnel. The analysis and discussions resulted in a list of 12 components and assemblies which were supplied to engineering personnel in the ATCA SPO. These components and assemblies were selected using the following criteria: (1) an AARB component or assembly was comparable to a similar or corresponding component or assembly which was a large logistics support cost contirubtor in the KC-135 boom system, or (2) an AARB component had no corresponding part in the KC-135 boom system yet it seemed likely

to add significantly to the logistics support cost. ATCA SPO personnel, using their experience, knowledge of the AARB design, and the baseline values supplied for the corresponding KC-135 variables, determined values for the appropriate variables for use in the logistics support cost analysis of the AARB. A thorough discussion of the AARB analysis can be found in Chapter IV.

The values for the AARB variables that were supplied were then analyzed with regard to the historical experience on the KC-135 boom. The final values that were agreed upon between ATCA SPO personnel and the researchers were entered into the model, and the AARB logistics support cost estimate was obtained.

Because of the uncertainty that existed in the initial values for the AARB variables, sensitivity analyses were conducted on selected variables to determine the effect of the changes in the variables on the AARB logistics support cost estimate. A thorough discussion of these sensitivity analyses can be found in Chapter V.

Thesis Presentation Plan

Chapter I has presented an introduction to, background, and an overview of the research study. The significance, assumptions, limitations, and methodology were also discussed.

Chapter II describes the LSC Model and the assumptions and limitations associated with it. The adaptations

of the LSC Model developed for this analysis are also discussed.

Chapter III contains a description of the KC-135 boom system and a detailed discussion of the collection of the information required for the logistics support cost analysis of this system. Chapter IV describes the AARB and the steps required to arrive at a point where a comparative logistics support cost analysis could be performed. Chapter V describes the sensitivity analyses that were performed on the variables used in the AARB logistics support cost estimate.

Chapter VI contains a summary and presents some conclusions and recommendations which resulted from this research.

The appendices contain supplementary material which will be of greatest use to those who are actually using the LSC Model.

II. The Model

This chapter presents the Air Force Logistics Command Logistics Support Cost (AFLC LSC) Model and the adaptations to it which were developed for the comparative analysis of the two aerial refueling boom systems. For convenience, the adapted model will hereinafter be referred to as the Boom Model. This chapter also presents detailed explanations of each of the Boom Model equations and a short description of each of the model variables. A detailed description of each variable can be found in Appendix A. Chapters III and IV discuss the analyses of the existing KC-135 boom and the proposed Advanced Aerial Refueling Boom (AARB) respectively.

The LSC Model

The LSC Model is designed to be used to estimate the logistics support costs that may be incurred by adopting a particular system design or configuration. Furthermore, it is intended to be used to discriminate between the costs of supporting alternative designs rather than to provide an accurate logistics support cost estimate (51:3-4). The logistics support costs of a system are the costs of ownership such as maintenance man-hours, parts inventories, facilities, support equipment, maintenance personnel training, record keeping, etc. It is these costs that are combined in the LSC Model to estimate the logistics support cost figures of merit for alternative weapon systems.

The significance of the calculated logistics support costs is not their absolute magnitudes, rather it is the relative magnitude of the difference in costs between the alternatives tested (51:4). This means, for example, that the significant fact is not that the one system will cost one billion dollars to support over the next ten years and that the other system will cost three billion dollars to support. Rather, the significant fact is that it will cost two billion dollars more to support one system than it will cost to support the other system.

Specifically, the Model Handbook says the LSC Model is intended to be used in one or more of the following ways (51:4):

1. To obtain an estimate of the differential logistics support costs between the proposed design configurations of two or more contractors during source selection.
2. To establish a baseline for contractual commitments on certain aspects of operational supportability which will be subject to verification.
3. To use as a decision aid in discriminating among design alternatives during prototyping or full-scale development.

In this research study, the LSC Model, as adapted, is used to obtain an estimate of the differential logistics support costs between two alternative designs. The two designs are the existing KC-135 boom and the Douglas Aircraft Company's AARB.

<u>Characteristics</u>. The LSC Model consists of ten separate equations, each of which computes the cost for a particular facet of logistics support (e.g., on-equipment maintenance, support equipment, personnel training). The

total logistics support cost of the weapon system is the sum of the costs calculated by each of the ten equations. In the Boom Model, the number of equations was reduced to eight because the last two equations of the basic LSC Model applied to propulsion systems.

In the model, the basic unit of hardware for which costs are accumulated is the First Line Unit, or FLU. According to the Model Handbook, a FLU is

> . . . the first level of assembly below the system level that is carried as a line item of supply at base level and is usually the highest level of assembly that is removed and replaced, as a unit, on the complete system or subsystem in order to return the equipment to operational condition [51:1-1].

Typical FLUs are landing gears, hydraulic motors, and avionics black boxes. The model equations then use particular FLU characteristics, such as mean time between failures and unit cost, to compute the appropriate logistics support costs. The FLUs combine to make systems, and the systems form the weapon system. This approach of starting at lower levels and combining costs into higher levels is called the accounting approach, and this type of model is called an accounting model (30:55).

The LSC Model is a general model that, in most cases, has to be tailored to fit the specific analytical situation. Since not all weapon systems are identical, some of the model equations and variables may not be appropriate in every case, and they should be deleted or changed as required. It may be necessary to redefine some of the variables in order to model the situation more realistically. For example, if the factor

that produces failures or maintenance actions is based on flying hours rather than operating hours, the appropriate variable to use in the model is the mean flying time between failures rather than the mean operating time between failures.

On the other hand, it may be necessary to add new equations and variables to more realistically model the situation. As an example, if the weapon system contains many computers, it would be appropriate to add an equation and variables that capture the unique costs associated with computers and computer software.

<u>Variables</u>. The complete LSC Model contains 94 different variables. Complete descriptions of the 57 Boom Model variables, including dimensional units, appear in Appendix A. However, the model variables fall into three general categories.

1. Weapon System Variables. These variables describe the known or proposed operational use of the weapon system. Representative program variables are (a) the number of bases that provide intermediate maintenance and support (M), (b) the number of years included in the logistics support cost analysis--the program inventory usage period (PIUP), and (c) the total number of flying hours over the period (TFFH).

2. System Variables. These variables describe the known or proposed design parameters of the functional systems within the weapon system. Representative system variables

are (a) the number of FLUs within the system (N), (b) the costs of training base level maintenance personnel to maintain the system (TCB), and (c) the costs of base and depot facilities required to support the system (FB and FD respectively).

3. FLU Variables. These variables describe the design characteristics of the components. Representative FLU variables are (a) the unit acquisition cost of the FLU (UC), (b) the mean time between failures for the FLU (MTBF), and (c) the not reparable this station rate for the FLU (NRTS).

Also, there are variables that do not describe weapon system peculiar characteristics. Rather, these Government Standard Variables describe characteristics that do not vary between weapon systems. They are based on historical data. Representative government standard variables are (a) base labor rate (BLR), (b) base personnel turnover rate (TRB), and (c) base and depot repair cycle times (BRCT and DRCT respectively). The data for these variables are furnished by the Air Force. The current values can be found in the latest edition of the Model Handbook (51).

<u>Assumptions</u>. The LSC Model is based upon the following assumptions which also apply to the Boom Model (51:5-6):

1. The model assumes a constant, uniform level of program activity--flying hours--at each base.

2. The model computes base and depot repair pipeline stock levels on the basis of the peak level of program

activity--the maximum number of flying hours in any one month period. This computation results in base and depot repair pipelines stock levels that are higher than would be needed for a normal monthly level of program activity.

3. The model computes logistics support costs for the weapon system, system, and FLU indenture levels. The logistics support costs of components and assemblies below the FLU level are considered only implicitly by their use in the repairs of the higher level FLUs.

4. The model assumes that there is only one depot repair location and any number of bases (M) which provide intermediate (base shop) maintenance and support.

5. The model assumes that initial and follow-on training costs are identical. In other words, the costs of Type I training (basic technical school training) are the same as the costs that the contractor charges to train the initial cadre of maintenance personnel.

Limitations. Mathematical models never perfectly describe the situations they are intended to represent. They should be simple enough to be practical, within reasonable constraints of time and money, yet detailed enough to insure that the essential relationships being modeled are adequately captured. The following limitations are relevant to the analytical use of the LSC Model.

1. The LSC Model does not capture all of the logistics support costs that actually contribute to the cost of the weapon system over its lifetime, and the magnitude and

significance of the omitted costs is not known. These omitted costs fall into two categories: those which are not design sensitive and those which are design sensitive.

The non-design sensitive costs which are omitted include many overhead, fixed, and personnel costs associated with the maintenance and supply organizations at the bases and the depot. Some costs, such as modifications and programmed depot maintenance, are excluded because it would be impossible to foresee any discernible difference between design alternatives. Also, the model only captures the cost of direct man-hours to maintain or repair the equipment. This means that the cost of manpower utilized is considered rather than the cost of manpower available. However, this approach more directly relates the costs to the particular system designs.

In the case of the design sensitive costs, there are two types of omitted costs. First, are costs which are purposefully omitted, when possible, because they are not relevant to the analyses. These include the sunk costs and the costs which would be identical for the alternatives being considered. Second, there are costs which are design sensitive but which are not accounted for in the model and consequently limit the validity of the resulting logistics support cost figures of merit. The model does not capture the cost of those FLUs condemned at the depot. This cost may be significant if, by policy or direction, the FLUs are only condemned at the depot. The model does not account for lower than FLU

level parts that are repaired or replaced while the FLU is installed on the aircraft; however, such repairs are accounted for in the equation which computes off-equipment maintenance cost. The model does not consider the costs associated with maintaining, changing and updating technical data. Finally, the model does not account for the costs associated with those FLUs and other parts which are not among the FLUs selected for the analysis. The missing costs may obscure or magnify the apparent significance of the true difference in life cycle logistics support costs. For example, a 5 million dollar difference in logistics support costs between two alternatives that cost 20 and 25 million dollars may seem less significant than a 5 million dollar difference between two alternatives that cost 5 and 10 million dollars. What is thought of as the logistics support costs of the weapon system are actually the logistics support costs of the selected FLUs. Decision makers must be made aware of this limitation of the logistics support cost figures of merit calculated by the LSC Model.

2. The LSC Model requires a great amount of input data. The use of accounting models, like the LSC Model, is frequently hampered by excessive data requirements (30:56). In most cases, data for the variables are just not available

in a convenient and usable form, and there are several reasons for this.

First, the definition of a FLU does not always correlate to the Work Unit Code (WUC) structure, and modifications are required. WUCs are five-digit alphanumeric codes that identify a system, a major assembly or an individual component. When base level maintenance is performed, it is recorded against the WUC of the component worked on. Since not every component has its own WUC, and in some cases, parts within the FLU have unique WUCs, improper reporting occurs. For example, there are six components within the boom nozzle that have their own unique WUCs. This situation adds to the difficulty of collecting data for use in the model.

For an existing system, such as the KC-135 there is not any single source of logistics support cost data. Instead, the data for this study had to be drawn from many data sources. Correlation of data between data sources is quite low because the various data sources were designed for different purposes, which do not include weapon system cost accounting (34:4-5). These data source problems limit the accuracy and relevance of any cost study, such as this one.

To compound the data problems even more, base level maintenance data collection is by WUC while depot level data is collected by national stock number (NSN). The fact that there is no WUC/NSN master cross reference greatly complicates the data collection problem.

3. The LSC Model contains some variables which defy objective evaluation because they were devised to model a situation for which no data is collected. The uncertainty inherent in these variables is an inescapable limitation on the accuracy of the LSC figures.

4. The LSC Model is frequently used relatively early in the acquisition process. This is when the design is more likely to be flexible and trade-offs would seem most feasible. However, very little factual data is available early in a program upon which to base comparisons. It is likely that estimates made early in the system life cycle could have relatively more uncertainty associated with them. The Logistics Management Institute (49:7) says that

> Except for an occasional subsystem, meaningful operation and support cost estimates almost never are obtainable before Engineering Development and can be elusive until conditions are satisfied for award of a production contract.

Table I (page 26) is adapted from an AFLC Deputy Chief of Staff for Acquisition Logistics briefing on logistics models (52). It shows that the verifiability of data increases as the life cycle of the system progresses.

The following section describes in detail the Boom Model, which was modified from the LSC Model in order to overcome some of the limitations of the LSC Model and to take advantage of available data which applied to the KC-135 boom system.

Table I
Verifiability of Equipment Parameters

	STAGES OF SYSTEM DEVELOPMENT			
CRITICAL ELEMENTS	SOURCE SELECTION	FULL SCALE DEVELOPMENT	TEST	EARLY OPERATION
Demand Rates (MTBF)	Very Limited	Limited	Indication	Yes
Unit Cost	No	No	Very Limited	Yes
AGE Cost	No	No	No	Yes
Repair Times	Very Limited	Limited	Indication	Yes
Material Cost	No	No	No	Limited
Extent of Repair (NRTS, COND)	Very Limited	Indication	Indication	Indication
Fuel Consumption Rate	Limited	Indication	Yes	Yes

The Boom Model

The Boom Model, an adaptation of the LSC Model, estimates the logistics support cost figures of merit for the two aerial refueling boom system designs--the existing KC-135 boom and the proposed AARB. The model consists of eight equations, each of which computes a portion of the total logistics support cost. The total logistics support cost (LSC), then, is the sum of the costs for each of the eight equations. Therefore, LSC is

$$LSC = \sum_{p=1}^{8} C_p$$

The eight logistics support cost equations are (where N represents the number of FLUs included in the analysis):

$$C_1 = \sum_{i=1}^{N} \text{ Cost of Initial and Replacement FLU Spares}$$

$$C_2 = \sum_{i=1}^{N} \text{ Cost of On-Equipment Maintenance}$$

$$C_3 = \sum_{i=1}^{N} \text{ Cost of Off-Equipment Maintenance}$$

$$C_4 = \sum_{i=1}^{N} \text{ Cost of Inventory Entry and Supply Management}$$

C_5 = Cost of Support Equipment

C_6 = Cost of Personnel Training

C_7 = Cost of Records Management and Technical Data

C_8 = Cost of New Facilities

Equations C_1 through C_8 correspond to the first eight equations in the LSC Model. C_1 and C_8 are identical to the corresponding LSC Model equations.

The following text explains, in detail, each of the eight equations as if there were one system--the boom system--and "N" FLUs in that system. A short description of each variable is given when it appears in the equations. A detailed description of each variable is given in Appendix A. The modifications to the LSC Model that make up the Boom Model are identified at the end of the equations in which they occur.

The Cost of Initial and Replacement Spares

$$C_1 = M\sum_{i=1}^{N}(STK_i)(UC_i) +$$

$$\sum_{i=1}^{N}\frac{(PFFH)(QPA_i)(UF_i)(1-RIP_i)(NRTS_i)(DRCT_i)}{MTBF_i}(UC_i) +$$

$$\sum_{i=1}^{N}\frac{(TFFH)(QPA_i)(UF_i)(1-RIP_i)(COND_i)}{MTBF_i}(UC_i)$$

Equation C_1 consists of three parts, as follows,

$$C_1 = \left[\text{Cost to fill base repair pipeline}\right] +$$

$$\left[\text{Cost to fill depot repair pipeline}\right] +$$

$$\left[\text{Cost to replace FLUs condemned at base level}\right]$$

The cost to fill the base repair pipeline. The first part of C_1 represents the cost to fill the base repair pipeline. That is,

$$M \sum_{i=1}^{N} (STK_i)(UC_i)$$

where STK_i is the number of spares of the i^{th} FLU required to fill the base repair pipeline, UC_i is the unit cost of the i^{th} FLU, and M is the number of bases that provide intermediate maintenance and support for the weapon system. The calculation of STK_i includes a safety stock to absorb variations in demand and lead time.

The calculation of STK_i involves finding the minimum value of STK_i such that

$$\sum_{x>STK_i} (x-STK_i)p(x|\lambda_i t_i) \leq EBO$$

where x is the number of demands on base supply and $\lambda_i t_i$ represents the expected number of demands for the FLU over its average base repair pipeline time (t_i). The distribution of probabilities of demands, given a mean demand ($\lambda_i t_i$), is assumed to follow a Poisson distribution.

In this expression, the left-hand side of the inequality represents the expected number of demands in excess of supply--backorders--which must be less than or equal to the standard established for expected backorders, EBO. For smaller values of EBO the equation calculates a larger number of spares for each FLU, depending on the values calculated for λ_i and t_i.

The mean demand rate per base during the peak month is calculated from the input variables as follows:

$$\lambda_i = \frac{(PFFH)(QPA_i)(UF_i)}{MTBF_i} \times \frac{(1-RIP_i)}{M}$$

where PFFH is the peak force flying hours per month, QPA_i is the quantity of the i^{th} FLU on the aircraft, and UF_i is the use factor for the FLU. MTBF is the mean time between failures for the FLU which translates, for purposes of this computation, to time between demands upon the supply system. This equation, then, is equivalent to,

$$\lambda_i = \left[\begin{array}{l}\text{Peak demands}\\\text{per month}\end{array}\right] \times \frac{(1-RIP_i)}{M}$$

where $1-RIP_i$ is the fraction of FLU failures that is removed from the aircraft--the fraction that is not repaired in-place (RIP). Dividing by M makes λ_i an average demand rate per base.

The weighted average base repair pipeline time for the i^{th} FLU (t_i) in months is calculated as follows:

$$t_i = (RTS_i)(BRCT_i) + (NRTS_i)[(OSTCON)(1-CS) + (OSTOS)(OS)]$$

which is to say,

$$t_i = \left[\begin{array}{l}\text{Weighted average base}\\\text{repair cycle time}\end{array}\right] + \left[\begin{array}{l}\text{Weighted average depot}\\\text{replacement time}\end{array}\right]$$

where RTS_i is the fraction of removed FLUs that is reparable this station and BRCT is the average base repair cycle time. $NRTS_i$ is the fraction of removed FLUs that is not reparable this station and therefore sent to the depot for overhaul.

The time it takes to get a replacement from the depot is dependent upon the fraction of the total force that is deployed overseas (OS) and the average shipping time to overseas (OSTOS) and continental United States (OSTCON) locations.

The cost to fill the depot repair pipeline. The second part of C_1 represents the cost of filling the depot repair pipeline. This is

$$\sum_{i=1}^{N} \frac{(PFFH)(QPA_i)(UF_i)(1-RIP_i)(NRTS_i)(DRCT_i)}{MTBF_i}(UC_i)$$

where the product of the number of failures of the i^{th} FLU that are removed from the weapon system during the peak month for all bases

$$\frac{(PFFH)(QPA_i)(UF_i)(1-RIP_i)}{MTBF_i},$$

the number of removed i^{th} FLUs that are not reparable at base level ($NRTS_i$), and the average depot repair cycle time for the i^{th} FLU ($DRCT_i$) gives the number of the i^{th} FLU that must be in the depot repair pipeline in order to support the total force during the peak month. Multiplying this expression by the unit cost of the i^{th} FLU (UC_i) and summing the costs for all "N" FLUs gives the logistics support cost for all FLUs that are in the depot repair pipeline.

The cost to replace FLUs condemned at base level. The last part of C_1 represents the cost of replacing those

FLUs that are condemned at base level. This is

$$\sum_{i=1}^{N} \frac{(TFFH)(QPA_i)(UF_i)(1-RIP_i)(COND_i)}{MTBF_i}(UC_i)$$

or,

$$\sum_{i=1}^{N} \left[\begin{array}{l}\text{Total lifetime}\\ \text{FLU failures}\end{array}\right] (1-RIP_i)(COND_i)(UC_1)$$

Multiplying the total number of failures of the i^{th} FLU by the fraction of FLU failures removed from the airplane $(1-RIP_i)$, and the fraction of those removed FLUs that are condemned $(COND_i)$, gives the total number of the i^{th} FLU that will be condemned. Multiplying this number by the unit cost of the i^{th} FLU (UC_i) gives the total cost of condemnations of the i^{th} FLU. Then summing the costs for all of the "N" FLUs gives the total logistics support cost of those FLUs that were condemned at base level.

Summary and comments. Equation C_1, the cost of initial and replacement spares, is then the sum of the three terms for base and depot repair pipeline spares plus replacement spares. This equation is identical to the corresponding LSC Model equation; however, the Boom Model handles the computation differently for an existing system. The costs associated with stocking base and depot pipelines are sunk costs for the KC-135. Therefore, the only relevant costs in this case are replacement costs and the first two terms are omitted.

The Cost of On-Equipment Maintenance

$$C_2 = \sum_{i=1}^{N} \frac{(TFFH)(QPA_i)(UF_i)}{MTBF_i} [(RIP_i)(IMH_i) + (1-RIP_i)(RMH_i)](BLR) + 4(SHQ)(PIUP)(BLR)$$

Equation C_2 can be broken into two parts. In general,

$$C_2 = \begin{bmatrix}\text{Cost of unscheduled}\\ \text{on-equipment}\\ \text{maintenance}\end{bmatrix} + \begin{bmatrix}\text{Cost of scheduled}\\ \text{on-equipment}\\ \text{maintenance}\end{bmatrix}$$

The cost of unscheduled on-equipment maintenance. The first part of C_2 can be written,

$$\sum_{i=1}^{N} \begin{bmatrix}\text{Total lifetime}\\ \text{FLU failures}\end{bmatrix} [(RIP_i)(IMH_i) + (1-RIP_i)(RMH_i)](BLR)$$

where the element $[(RIP_i)(IMH_i) + (1-RIP_i)(RMH_i)]$ is the weighted average time it takes to either fix a failure of the i^{th} FLU while it is in-place on the weapon system (IMH_i) or remove and replace the FLU (RMH_i) as appropriate. BLR is the base labor rate.

Multiplying the weighted average unscheduled on-equipment maintenance time by the total number of failures of the i^{th} FLU gives the total number of man-hours spent on

unscheduled on-equipment maintenance for the i^{th} FLU. Multiplying these total man-hours by the base labor rate (BLR), in dollars per man-hour, gives the total cost of unscheduled on-equipment maintenance on the i^{th} FLU.

Then summing these costs for all of the "N" FLUs gives the logistics support cost of unscheduled on-equipment maintenance for all of the FLUs at all bases.

The cost of scheduled on-equipment maintenance. The second part of C_2 represents the cost of scheduled on-equipment maintenance. This is

$$4(SHQ)(PIUP)(BLR)$$

where SHQ is the total number of man-hours spent on scheduled maintenance for all of the FLUs for one calender quarter and PIUP is the program inventory usage period or assumed life of the system. Multiplying this product by the base labor rate (BLR) gives the logistics support cost of scheduled on-equipment maintenance for all of the FLUs at all bases for the assumed lifetime of the system.

Summary and comments. The total logistics support cost of on-equipment maintenance, Equation C_2, is the sum of the unscheduled and scheduled on-equipment maintenance costs.

This equation has been modified from the corresponding LSC Model equation in the following ways:

1. In the first part of C_2, a variable for the man-hours required to gain access to the FLU prior to beginning repair or removal actions was eliminated because it was not

possible to breakout such data from the available data system products. Rather, it was assumed that the IMH (in-place man-hour) and the RMH (remove and replace man-hour) values included this access time.

2. The second part of C_2, the cost of scheduled on-equipment maintenance was changed because it was not possible to get a value for the time interval between scheduled maintenance actions. Besides the phase inspections, reported scheduled maintenance includes time for preflight, postflight and other regular preventive maintenance inspections for which an interval would be impossible to estimate (77: III-01). However, it was possible to obtain the total number of scheduled on-equipment man-hours so this figure was used as described above.

The Cost of Off-Equipment Maintenance

Off-equipment maintenance is that repair done in the base shops and at the depot.

$$C_3 = \sum_{i=1}^{N} \frac{(TFFH)(QPA_i)(UF_i)(1-RIP_i)}{MTBF_i} \{(RTS_i)[(BMH_i)(BLR+BMR) + (BMC_i)(UC_i)] + (NRTS_i)(DMX_i) + [2(NRTS_i) + COND_i][(PSC)(1-OS) + (PSO)(OS)](1.35W_i)\}$$

This equation can be expressed as

$$C_3 = \sum_{i=1}^{N} \left[\text{Total number of failed removed FLUs}\right] \left[\text{Weighted average cost per FLU removed from aircraft}\right]$$

Number of failed FLUs removed for repair. This expression in equation C_3 represents the total number of the i^{th} FLU failures that are removed from the weapon system during the assumed life of the system. This is

$$\frac{(TFFH)(QPA_i)(UF_i)(1-RIP_i)}{MTBF_i}$$

where the product of the total number of FLU failures and the fraction of the FLU failures that are removed from the weapon system ($1-RIP_i$) gives the number of FLU failures that are sent to the base shops for repairs or other maintenance actions.

Cost to repair a FLU in the base shops. The second expression in equation C_3 represents the cost per failure of fixing a removed FLU in the base shops. This is

$$(RTS_i)[(BMH_i)(BLR + BMR) + (BMC_i)(UC_i)]$$

where the product of the fraction of removed FLUs that are repaired at base level (RTS_i) and the average cost per removed FLU gives the average cost per FLU failure for base shop maintenance. The average base shop maintenance cost per removed FLU is

$$(BMH_i)(BLR + BMR) + (BMC_i)(UC_i)$$

where the product of the average number of hours to repair a FLU failure in the base shops (BMH_i) and the sum of the base labor rate and base consumable materials rate (BLR and BMR respectively) in dollars per man-hour, gives the average direct cost to repair a FLU in the base shops. The product of the average cost of labor for repair of lower level components within the FLU (BMC_i) and the unit cost of the FLU gives an average indirect labor cost per FLU failure for the repair of lower level components.

Then the sum of these two costs gives the average cost per FLU failure for base shop repair. However, once the removed FLU is in the base shops it may not be possible to repair it at the base level, and other actions are required.

Cost to repair a FLU at the depot. The third expression in equation C_3 represents the cost per failure of fixing a FLU at the depot. This is $(NRTS_i)(DMX_i)$ where $NRTS_i$ represents the fraction of removed FLUs that cannot be repaired at the base level and DMX_i represents the average depot repair cost for those FLUs sent to the depot.

Cost for FLU transportation. The last expression in equation C_3 represents the cost of transporting FLUs to and from the depot. This is

$$[2(NRTS_i) + COND_i][PSC(1-OS) + (PSO)(OS)](1.35W_i)$$

which can be written as,

$$\begin{bmatrix}\text{Fraction of failed}\\ \text{FLUs transported}\end{bmatrix}\begin{bmatrix}\text{Weighted average}\\ \text{packing \& shipping cost}\end{bmatrix}(1.35W_i)$$

If it is determined that a removed FLU must be sent to the depot for repair, then transportation charges occur when the failed FLU is sent from the base to the depot and its replacement is sent from the depot to the base. If the FLU is condemned at the base level, then the only transportation charge is for sending the replacement FLU from the depot to the base.

The weighted average packing and shipping cost is [(PSC)(1-OS) + (PSO)(OS)] where PSC is the average packing and shipping cost to locations within the continental United States and PSO is the average packing and shipping cost to overseas locations. The term (1-OS) represents the fraction of the total force which is based in the continental United States and OS represents the fraction deployed overseas.

The product of the number of times per failure that a removed FLU is transported, the average cost of packing and shipping the FLU, and 1.35 times the weight of a FLU gives the cost per failure of transporting a FLU. The factor 1.35 is the ratio of packed to unpacked weight.

Summary and comments. Summing the weighted average cost of repairing a removed FLU in the base shops, the weighted average cost of repairing the FLU at the depot, and the weighted average cost of transporting the FLU gives the average cost per failure of off-equipment maintenance for the FLU. Then multiplying by the total number of FLU failures gives the logistics support cost for off-equipment maintenance of the i^{th} FLU.

Finally, summing the logistics support costs for all "N" FLUs gives the total logistics support cost for off-equipment maintenance for all FLUs, or Equation C_3.

This equation has been modified from the corresponding LSC Model equation in the following ways:

1. In the second expression, a variable representing the average number of man-hours to shop bench check a

removed FLU, was eliminated because there was no way to separate that time from the actual repair time in the available data products. It was assumed that BMH included the time required to troubleshoot a failed item.

2. In the third expression, DMX was substituted for three variables representing the depot man-hours, materials and lower level parts and assemblies replaced during depot overhead. The factors that made up DMX were auditable depot costs and included condemnations that occurred at the depot, as well as labor, material and overhaul expenses.

<u>The Cost of Inventory Entry and Supply Management</u>

$$C_4 = [IMC + (PIUP)(RMC)]\sum_{i=1}^{N}(PA_i+1) + (M)(SA)(PIUP)\sum_{i=1}^{N}(PA_i + SP_i + 1)$$

This equation can be broken into two parts. In general,

$$C_4 = \begin{bmatrix}\text{Cost to enter new item into government} \\ \text{inventory and manage over lifetime}\end{bmatrix} + \begin{bmatrix}\text{Cost of base supply} \\ \text{inventory management}\end{bmatrix}$$

<u>The cost of government inventory management</u>. The first part of C_4 represents the cost of entering new line items of supply into the government inventory and managing them over the assumed life of the weapon system. This is

$$[IMC + (PIUP)(RMC)]\sum_{i=1}^{N}(PA_i+1)$$

where the sum of the initial management cost per line item of supply (IMC) and the product of the program inventory usage period (PIUP) and the recurring management cost per line item of supply (RMC) gives the cost per line item of

supply of entering a new line item into the government inventory and managing it over the assumed life of the weapon system.

The term (PA_i+1) represents the number of new line items of supply that enter the government inventory and have to be managed. The factor "1" represents the i^{th} FLU itself, and the factor PA_i represents the number of additional new "P" coded (procured) reparable subassemblies and consumable components within the FLU. Summing the number of new line items of supply for each of the "N" FLUs gives the total number of new items. Then multiplying the number of new items by the cost to manage an item of supply gives the logistics support cost.

Cost of base supply inventory management. The second part of C_4 represents the cost of managing both new and already stocked supply items at base level over the assumed life of the weapon system. This is

$$(M)(SA)(PIUP)\sum_{i=1}^{N}(PA_i + SP_i + 1)$$

where the sum of the number of new "P" coded line items of supply in the i^{th} FLU (PA_i), the number of already stocked supply items in the i^{th} FLU that will be managed for the first time at bases where the weapon system is deployed (SP_i) and "1" gives the number of supply items in the i^{th} FLU that will be managed for the first time at bases where the weapon system is deployed. Multiplying by the product of the number

of bases (M), the average annual base supply management cost (SA), and the program inventory usage period (PIUP) gives the logistics support cost of inventory management for new line items of supply at all bases over the life of the weapon system.

Summary and comments. Finally, the sum of the cost of entering new line items of supply into the government inventory and managing them, and the cost of managing new line items of supply at bases where the weapon system is deployed, gives the total logistics support cost of inventory entry and supply management over the life the weapon system, or Equation C_4.

There is only one modification to this equation from the corresponding LSC Model equation. In this equation, the variable PA represents the total number of new "P" coded (procured) reparable subassemblies and consumable components in the FLU rather than using two variables, one for reparable items and one for consumable items, as the LSC Model does.

For the KC-135 boom system analysis the first part of C_4 is simplified because IMC is a sunk cost, and PA is equal to zero.

The Cost of Support Equipment

$$\boxed{C_5 = \text{SECOST}}$$

Equation C_5 has only one term. SECOST represents the total cost of new base level support equipment required to maintain the boom system. It includes the cost of flight-line and base shop support equipment. Also, it includes the cost of computer software for automatic test equipment and any interconnecting hardware for existing automatic test equipment that might be used to support or repair the boom system or its components.

Comments. This equation is a radical change from the corresponding LSC Model equation. It was impossible to get data for some of the LSC Model support equipment variables for the KC-135 boom. In addition, it would have been impossible to estimate the support equipment for the AARB in the detail required for the LSC Model.

The support equipment for the KC-135 was assumed to be a sunk cost and was therefore equal to zero. The cost of operation and maintenance of the support equipment was assumed to be insignificant for the aerial refueling boom system.

The Cost of Personnel Training and Training Equipment

$$C_6 = [1 + (PIUP-1)(TRB)][(TCB)(MENB) + (TCA)(MENA)] + TE$$

Equation C_6 consists of two parts. In general,

$$C_6 = \begin{bmatrix}\text{Cost of personnel} \\ \text{training}\end{bmatrix} + \begin{bmatrix}\text{Cost of training} \\ \text{equipment}\end{bmatrix}$$

The cost of personnel training. The first part of equation C_6 represents the cost of training base level maintenance personnel to maintain the system over its assumed life. This is

$$[1 + (PIUP-1)(TRB)][(TCB)(MENB) + (TCA)(MENA)]$$

where the calculation involves the product of the number of men that must be trained over the assumed life of the weapon system and the cost of training the men.

The product of the program inventory usage period minus one year (PIUP-1) and the annual base maintenance personnel turnover rate (TRB) gives the number of times that a complete new complement of maintenance personnel must be trained in the out-years. Adding "1" gives the number of times that a complete new complement of maintenance personnel must be trained. This assumes that a complete new complement is trained the first year.

The product of the average cost of training one inflight refueling system specialist (TCB) and the average number of men in an inflight refueling shop (MENB) gives the cost of training a complement of inflight refueling specialists. Similarly, the product of the average cost of training one avionics specialist to maintain the fly-by-wire system (TCA) and the average number of avionics specialists that will receive the training (MENA) gives the cost of training a complement of avionics, fly-by-wire, specialists. The sum of these complements of maintenance specialists gives the cost of training a complete complement of maintenance specialists to support the boom system.

For the KC-135 boom system, the first part of equation C_6 reduces to (PIUP)(TRB)(TCB)(MENB). This occurs because the system only requires inflight refueling specialists and the existing complement of specialists are already trained. Therefore, just (PIUP)(TRB) number of complements need to be trained.

Training equipment. The last part of equation C_6 represents the cost of new training equipment (TE) that is used for training the maintenance personnel on the boom system.

Summary and comments. The sum of the personnel training costs and the cost of training equipment gives the total logistics support cost of personnel training and training equipment, or Equation C_6.

This equation is a significant change from the corresponding LSC Model equation for the following reasons:

1. In the first place, this equation is simpler, and in the opinion of the writers, more closely represents the situation that is likely to exist. The LSC Model equation uses many variables, calculating the number of man equivalents based on man-hours.required to support the system and then multiplying by the cost of training per man.

2. The LSC Model equation includes the cost of training depot personnel. In the Boom Model, depot personnel training costs are included in the variable DMX, the cost of depot maintenance, in equation C_3.

3. An assumption inherent in this approach to the calculation of training costs is that the additional cost of personnel needed to maintain the electronic fly-by-wire control system for the AARB can be represented by one additional man in the base avionics maintenance shop. Of course this is pure speculation but does seem to be a reasonable approach to representing an unforeseeable situation. It has the additional advantage of being design sensitive in that it attempts to account for what are sure to be increased training requirements as a result of the introduction of a more advanced design into the inventory.

The Cost of Records
Management and Technical Data

$$C_7 = \sum_{i=1}^{N} \frac{(TFFH)(QPA_i)(UF_i)}{MTBF_i} [MRO + (1-RIP_i)(MR + SR + TR)](BLR) + (TD)(H)$$

Equation C_7 can be broken into two parts. In general,

$$C_7 = (\text{Cost of Records Management}) + (\text{Cost of Technical Data})$$

Cost of records management. The first part of equation C_7 represents the labor cost of keeping maintenance records for both on- and off-equipment maintenance, supply transactions, and transportation over the assumed life of the weapon system. This is

$$\sum_{i=1}^{N} \frac{(TFFH)(QPA_i)(UF_i)}{MTBF_i} [MRO + (1-RIP_i)(MRF + SR + TR)](BLR)$$

which can be expressed as

$$\sum_{i=1}^{N} \begin{bmatrix}\text{Total lifetime} \\ \text{FLU failures}\end{bmatrix} \begin{bmatrix}\text{Man-hours per FLU failure} \\ \text{to complete required forms}\end{bmatrix} (BLR)$$

The expression $[MRO + (1-RIP_i)(MRF + SR + TR)]$ is the number of hours per i^{th} FLU failure that it takes to complete the required records and forms. MRO is the average number of man-hours per failure required to complete on-equipment maintenance forms, and MRF is the similar figure for off-equipment maintenance. SR and TR are the average number of man-hours required to complete supply transaction records and tranportation forms, respectively.

Multiplying the average number of man-hours per i^{th} FLU failure that it takes to complete maintenance records and forms by the total number of i^{th} FLU failures over the assumed life of the weapon system gives the total number of man-hours spent to complete maintenance records and forms for i^{th} FLU failures over the assumed life of the weapon system. Further multiplication by the base labor rate (BLR) gives the labor cost associated with completing maintenance records and forms due to failures of each FLU. These costs are then summed over all FLUs.

Cost of technical data. The last part of equation C_7 represents the cost of procuring new technical data. This is (TD)(H) where the product of the cost per original page of technical data (TD) and the total number of new original pages of organizational, intermediate, and depot level technical data (H) gives the logistics support cost of new technical data.

Summary and comments. The sum of the logistics support costs of records management and technical data gives the

total logistics support cost of records management and technical data, or Equation C_7.

This equation has been modified from the corresponding LSC Model equation in the following ways:

1. Since all levels of maintenance use the same technical data and repair instructions, all types of technical data are represented by one variable, H, rather than two separate variables. This is a simplification, but it also eliminates the necessity of dividing the technical data into two groups, where in most cases the division would be arbitrary.

2. The term in the LSC Model equation that represents the labor cost of completing maintenance records and forms associated with scheduled maintenance activities was eliminated. As was explained for equation C_2, no realistic way was found to estimate the interval between scheduled maintenance activites so the term was eliminated, under the assumption that the costs would be relatively small in comparison to the total.

The Cost of New Facilities

$$\boxed{C_8 = (M)(FB) + FD}$$

or,

$$C_8 = \left[\begin{array}{l}\text{Cost of new}\\ \text{base facilities}\end{array}\right] + \left[\begin{array}{l}\text{Cost of new}\\ \text{depot facilities}\end{array}\right]$$

where FB is the cost of new base facilities required at each base to support the new system and FD is the cost of new facilities at the depot.

No changes were required to be made to this equation. The facilities required for the KC-135 are sunk costs and were set equal to zero for the KC-135 boom analysis.

These eight equations make up the Boom Model. Because of the large number of equations and variables, the only convenient method of performing the calculations is to use a computer. The next section describes the Boom Model computer program.

The Boom Model Computer Program

The LSC Model is programmed in FORTRAN and is available to all users of the AFLC CREATE computer system. Complete information for users can be found in the Model Handbook (51) which is available from AFALD/XRS, Wright-Patterson AFB, Ohio 45433.

The Boom Model computer program, because it is modified from the LSC Model computer program, is constructed so that the total logistics support cost for the weapon system and the system and FLU level logistics support cost contributions can be displayed in any of nine different output formats. A listing of these output data displays can be found in Appendix G.

The next chapter explains the KC-135 boom system analysis and methodology.

III. Analysis of the KC-135 Boom System

This chapter describes the analysis of the KC-135 boom system. It begins with some general comments and a detailed description of the KC-135 boom system in order to give the reader sufficient background information to enable him to understand the rationale behind some of the discussions which follow on the boom components. This chapter explains the methodology of breaking down the boom system into individual components, selecting the components to be included in the analysis, and then collecting data on the support cost parameters of these components so they could be used in the Boom Model for the logistics support cost analysis. In addition, it briefly describes and gives examples of those data products which the writers used for the analysis. For a complete listing and description of all of the variables used in the Boom Model and their corresponding values, the reader may turn to Appendix A and Appendix B respectively.

General Comments

It is intended that this chapter convey the methodology used in the KC-135 logistics support cost analysis so that others who may do similar studies can use this work as a starting point for their own efforts. It is recognized that the approaches used here will not fit every weapon system, if indeed they fit any other weapon system. Nevertheless, it is the intention of the writers that the methods

presented in this chapter suggest techniques which may be adapted for further studies on the same or on other weapon systems.

It should be remembered by future logistics support cost model developers that it is not very likely that they will be able to write a mathematical model independently of the available data sources, and then proceed to collect input data which will fall neatly into the categories defined for their model. Some of the changes that were made to the LSC Model, and described in Chapter II, were made in response to the availability of data.

In brief, the methodology consisted of: (1) breaking down the boom system into its component parts, (2) selecting the parts to be included in the analysis, (3) locating sources of data and determining values for the Boom Model variables, (4) tailoring the model where data availability or clarity indicated that changes needed to be made, and (5) computing the KC-135 boom system logistics support cost figure of merit. The whole analysis was iterative, especially between step (3), locating data, and step (4), arriving at a usable version of the model. The final version of the Boom Model was described in Chapter II.

Description of the KC-135 Boom System

The KC-135 aerial refueling boom system consists of a set of moveable, telescoping tubes that are attached to the underside of the aircraft by a forked bracket assembly called

the boom fork. The boom pivots in the fork for up and down movement. The shaft of the fork is positioned vertically and rotates when the boom is moved from side-to-side. The KC-135 boom pivot arrangement is shown in Figure 1. The boom fork is also shown in Figure 2 on page 57.

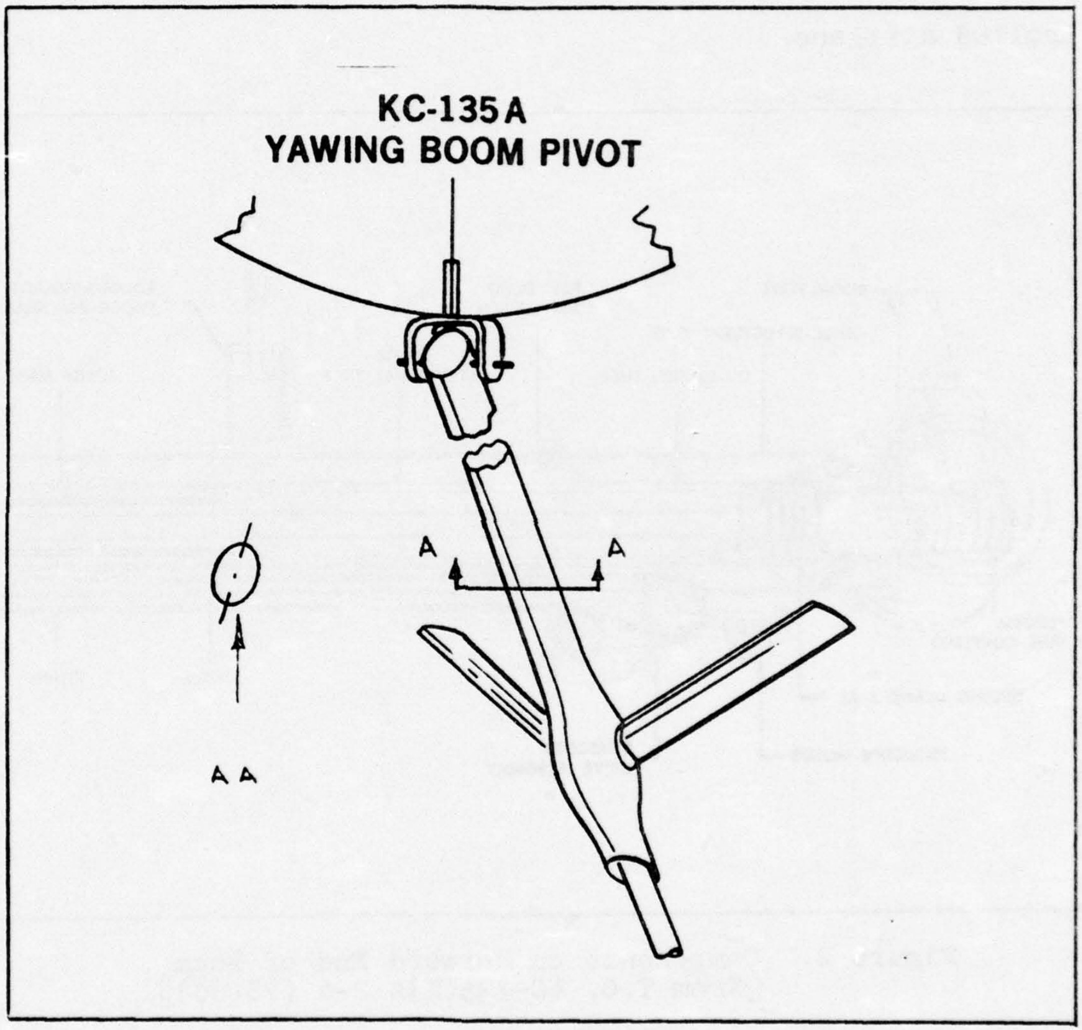

Figure 1. KC-135 Boom Pivot Arrangement--View Looking Aft [From AARB, Volume I, Technical Summary (3:2)]

The boom is maneuvered during refueling operations by moving a control level in the boom operator's station.

Control lever movements are transferred to the flight control surfaces, called ruddevators, by means of cables to hydraulic control units called the ruddevator boost units. The ruddevators form a "V" configuration at the aft end of the boom, as shown in Figure 1. The ruddevators take the place of the elevators and ailerons in a conventionally controlled airplane.

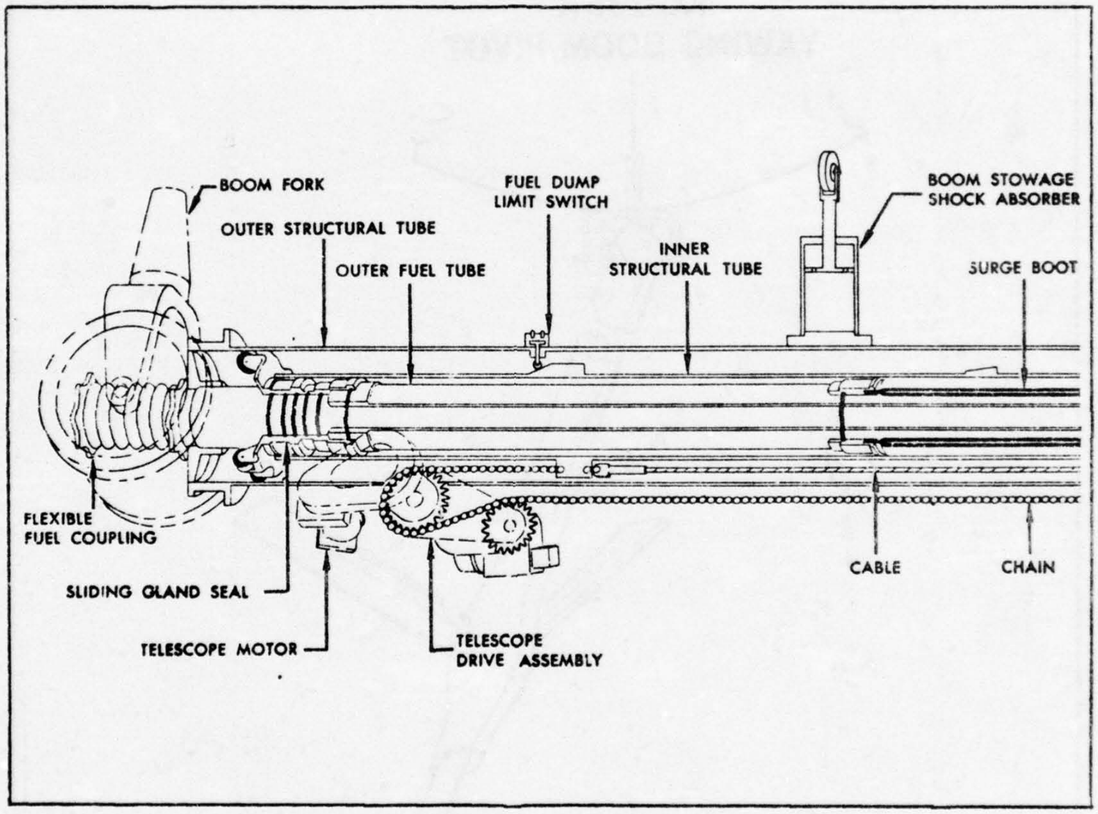

Figure 2. Components on Forward End of Boom
[From T.O. 1C-135(K)A-2-6 (78:60)]

The ruddevator shafts are mounted in the ruddevator quadrant, a diverse collection of brackets, sleeves and

bearings which also contain a ruddevator locking mechanism and the ruddevator boost units.

Related to the refueling boom, but not considered in this study, are three associated systems: (1) the boom operator's controls, (2) the receiver director lights, and (3) the boom hoist system. The boom operator's controls are located in the boom operator's station in the lower, aft fuselage section of the aircraft.

Two rows of receiver director lights are located along the bottom of the forward fuselage of the aircraft. These lights are visible to the pilot(s) of the receiver aircraft when the receiver is in the refueling position. The lights are operated either automatically by control units on the boom or manually by the boom operator. Position corrections, for the receiver, are indicated by the lights. The lights are not considered in this analysis but are mentioned in passing because the position sensing control units and transmitters which are part of the boom system are considered in this analysis.

The boom hoist system is located in the aft fuselage, and it is used in stowing the boom against the underside of the fuselage.

Forward and aft movement of the aerial refueling nozzle, which is located at the aft end of the boom, is accomplished through the telescoping of the main structural and fuel tubes. Telescoping is accomplished by means of a sprocket driven chain and cable. The sprocket is powered by

a hydraulic motor and reduction gearbox assembly, called the telescoping drive unit. A sliding gland seal is attached to the forward end of, and moves with, the inner structural tube to prevent fuel from leaking into the outer structural tube as the boom is extended and retracted. The seal, which is made up of a series of O-rings, teflon seals, felt wipers and metal spacers, held in grooves in a metal casing, slides along the stationary inner fuel tube.

Fuel pressure surges, caused by inadvertant disconnects while refueling, are absorbed by two tandem mounted rubberized surge boots which surround the last eight feet of the outer fuel tube. These flexible sleeves are pressurized with air, and are compressed against the surrounding inner structural tube when fuel surges through the perforations in the outer fuel tube.

Signals to operate the boom position indicating instruments, in the boom operator's station, are provided by three position transmitters. The transmitters are attached to the telescoping, elevation, and azimuth control units. Signals are provided by these controls for automatic operation of the receiver director lights; they also allow for automatic disconnect when the receiver aircraft moves outside the limits of the refueling envelope.

The aerial refueling nozzle is mounted at the aft end of the boom. When inserted, in the aerial refueling receptacle of the receiver aircraft, the nozzle is mechanically held in place by the toggles in the receptacle of the

receiver. The toggles are designed to fit into detents in the head of the nozzle. An integral, universal ball joint in the nozzle allows for slight misalignment of the tanker and receiver aircraft as the receiver moves about within the limits of the refueling envelope. The nozzle is shown in Figure 3 on page 61.

An induction coil, called the signal coil, is imbedded in the head of the nozzle. This coil completes an electrical circuit which runs between the signal coil amplifier in the tail of the tanker and the signal coil in the nozzle and also includes the electrical system of the receiver aircraft. When the electrical circuit between the tanker and the receiver is completed, the toggles of the receiver are automatically engaged, and the capability for automatic disconnect exists, if the limits of the refueling envelope are exceeded.

A recoil shock absorber is located just forward of the nozzle to absorb the shock forces associated with the nozzle connecting and disconnecting from the refueling receptacle of the receiver aircraft. Another shock absorbing unit, the ring spring assembly, is located just forward of the recoil shock absorber. The ring spring assembly absorbs the shock of the telescoping tubes contacting the travel stops.

The entire boom assembly is covered by aluminum skin panel fairings which provide continuity with the skin of the aircraft fuselage at the boom attachment point. The fairings

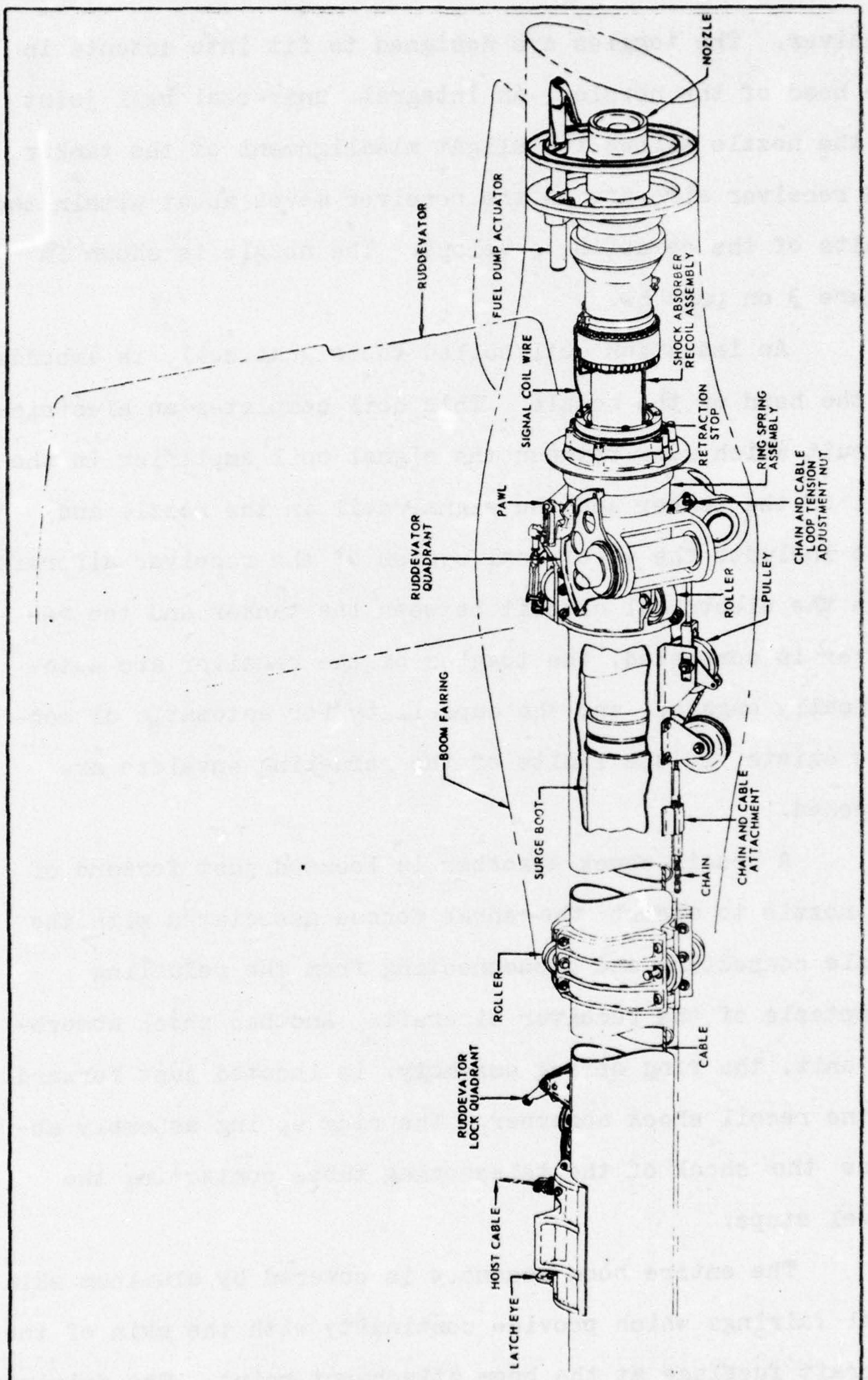

Figure 3. Components on Aft End of Boom [From T.O. 1C-135(K)A-2-6 (78;63)]

also provide protection for boom components and proper airflow over the boom surfaces.

The tailcone is the portion of fairing which covers the nozzle when it is in the fully retracted position. The tailcone also contains the fuel dump actuator, a hydraulically operated lever which operates in the event that an emergency situation necessitates dumping fuel to lower aircraft weight. The hydraulic lines and components associated with the fuel dump actuator are also located in the tailcone.

A boom stowage shock absorber is mounted on the top of the boom to prevent damage to both the boom and the aircraft when the boom is stowed against the fuselage. When the boom is stowed, a lever and roller assembly, called the ruddevator lock roller assembly, is depressed against the aircraft. This locks the ruddevators in the streamlined position by means of a mechanical linkage to the ruddevator quadrant.

This completes the functional description of the KC-135 boom system. The next section describes the process of breaking down the boom system into component parts for the logistics support cost analysis.

<u>Component Parts Breakdown</u>

To include every KC-135 boom component in the logistics support cost analysis would be an enormous task. Instead the analysis was limited to those few components which could be expected to contribute the bulk of the logistics support costs of the system.

The selection of these high cost components required a thorough knowledge of both the functional operation of the boom system and the cost performance of all of the major parts. The functional familiarization was done by using the following two technical orders: (1) T.O. 1C-135(K)A-2-6, Aerial Refueling System Organizational Maintenance Instruction Manual (78) and (2) T.O. 1C-135(K)A-4, Illustrated Parts Breakdown (81). T.O. 1C-135(K)A-2-6 explains the operation and the repair of the boom system. It gives reference to other technical orders for the repair of specific components and it lists all of the special tools and equipment required for each type of repair. T.O. 1C-135(K)A-4 shows detailed schematic diagrams and exploded views of all major assemblies and components. This manual also provides part nomenclature, quantities of each part in the system and identification of parts by part number. The part numbers were of little help in finding support cost information of components, but they were useful in finding the national stock numbers (NSN) of the parts, as will be explained.

To obtain cost information on components from the inventory management systems one needs the NSN, while retrieval of base level cost information requires the Work Unit Codes (WUC) of the components. The problems resulting from this difference in the reporting structure between depot and base levels are aggravated by the fact that there is no complete, official cross reference between WUCs and NSNs (34:5). Therefore, in order to compile a parts breakdown from

technical data and then correlate logistics support cost information from the various Air Force maintenance data collection systems, it was necessary to develop a cross reference which included part names, part numbers, WUCs and NSNs.

WUCs are five digit alphanumeric characters that identify specific levels of weapon system subdivision and are used in reporting base level maintenance actions. WUCs identify major subsystems by the first two digits, down to individual components, which are identified at the fourth or fifth digit positions. For example, the WUC 46000 identifies the aircraft fuel system, while 46771 identifies the boom nozzle assembly. The reference for KC-135 WUCs is T.O. 1C-135(K)A-06, Work Unit Code Manual.

In addition to the Work Unit Code Manual, other references were necessary in order to develop the parts breakdown and cross reference needed to correlate base and depot level logistics support cost data. The other documents used were

1. T.O. 1C-135(K)A-4, Illustrated Parts Breakdown. As previously noted, this technical order provided part numbers and nomenclature of all component parts.

2. D049, Full Range List. This is a data product which contains a complete listing of all components of a major recoverable end item (e.g., the KC-135 boom). The components are listed in part number sequence with a cross reference to the national stock number of each part. More

information on the D049 data product can be found in Appendix H and AFLCR 65-1, Master Material Supply Record (14).

3. K051.PN8L, Logistics Support Cost File Maintenance Register. This report, one of the data products from the Air Force Increase Reliability of Operational Systems (IROS) data system, contains a partial WUC to NSN cross reference. The report, however, reflects base reported data and contains many errors.

A brief explanation is interjected here to explain several data system "problems" which were encountered. Base level maintenance data is reported by a large number of people at many locations throughout the world. This in itself causes problems in communication and compliance. In addition, the complexity of the systems maintained and the structure of the reporting system lead to many possibilities for error. For example, completed maintenance is recorded on AFTO Forms 349, "Maintenance Data Collection Record." Codes must be recorded on this form for: (1) type of maintenance, (2) type of action taken, (3) how the malfunction occurred, (4) when the malfunction was discovered, and (5) the most appropriate WUC. This last causes many problems. The WUC structure is frequently confusing. Not all parts are coded. There are subcomponents with five digit WUCs which are contained within major components which also have five digit WUCs. Work accomplished on the subcomponent is frequently recorded against either the subcomponent or the major component. As noted recently by the Air Force

Inspector General in the TIG Brief (19:3),

> During July, August and September of 1975, nearly 1000 AFTO Forms 349 . . . for a particular type of aircraft were rejected from AFLC computer records due to inaccurate WUC reporting for on-equipment maintenance.

Because of problems in the WUC structure, it is likely that two maintenance personnel at different locations could report the same type of job against two different WUCs. If each used the same stock numbered replacement part, then that NSN would be reported as corresponding to both WUCs. No edit function exists to catch these errors due to the fact that no WUC-NSN master cross reference exists.

As previously stated, the purpose of the cross reference developed for this research was to enable the researchers to gather and correlate meaningful logistics support cost related information for the KC-135 boom analysis. Specifically, the cross reference was used to obtain information on the components, or First Line Units (FLUs), that were used in the analysis.

First Line Units. As explained in Chapter II, the Logistics Support Cost (LSC) Model, and consequently the Boom Model, are accounting type models. These models collect costs at the FLU level and then aggregate these lower level costs to arrive at a total weapon system level logistics support cost figure of merit. The purpose of this approach is to allow design sensitive comparisons for the purpose of evaluating alternatives.

According to the Model Handbook (51:1-1),

> A First Line Unit (FLU) is the first level of assembly below the system level that is carried as a line item of supply at base level and is usually the highest level of assembly that is removed and replaced, as a unit, on the complete system or subsystem in order to return the equipment to an operational condition. A FLU is assigned a unique WUC and is normally the first, second, or third level of assembly below the major system . . . .

The user of the LSC Model should not be misled by this last sentence in the belief that a list of major functional FLUs can be drawn up, each consisting of a single WUC and that base level data can then be read directly from the available reports by reference to this unique WUC. Due to problems with the data systems and the WUC structure mentioned above, it was decided to combine WUCs where subcomponents or other component WUCs contained much of the cost data which pertained to a major functional item or FLU. This was necessary in order to capture as much valid information as possible on the components.

In order to make up an initial list of components for this analysis, the K051.PN3L, "Logistics Support Cost Ranking, Work Unit Code Status Report," was used. This report, another product of the IROS system, shows for each WUC: (1) the cost of base level logistics support per month (labor only, but contains an application rate for overhead), (2) the percentage of the total weapon system cost accounted for by that WUC, and (3) the rank of the WUC as a consumer of logistics support resources in the entire weapon system. For example, an average of $6,058 was spent on WUC 46772, the

tailcone assembly, each month from July 1975 through September 1975; WUC 46772 was ranked as the 230th most expensive WUC in the KC-135 weapon system, and WUC 46772 accounted for .076 percent of the total logistics support cost for the KC-135 weapon system. These values are highlighted in the sample K051.PN3L report shown in Figure 4, page 69.

Using the K051.PN3L, the reported logistics support costs of identified boom components were listed in decreasing rank order. Some WUCs were combined into functional units, and when all components above the quarterly reported cost of $1000 were included, the total logistics support cost of these WUCs exceeded 85 percent of the total for all boom system WUCs. The total was obtained by adding the costs for each of the WUCs.

It was decided to limit the analysis to the components physically located on the boom, aft of the attachment point. This decision eliminated all components in the boom operator's station, including all boom controls. It also eliminated all components in the boom hoist system.

These omissions were believed not to have resulted in any significant errors. Available preliminary design information on the Advanced Aerial Refueling Boom (AARB) indicated that the AARB hoist system would be identical to the KC-135 boom hoist system, and the operator's station and controls were not yet defined to a degree which would allow a logistics support cost analysis.

WEAPON SYSTEM KC135A OCALC LOGISTIC SUPPORT COST RANKING RCS LOG-MMO(Q)7213(2) K051.PN3L PAGE 74
AFM 65-110/66-1 DATA AS OF 75 DEC WORK UNIT CODE STATUS DATE PROCESSED 76 FEB 0

WUC	NOUN	PERCENT SYSTEM	CAT IND	CURRENT QTR RANK	CURRENT QTR LSC	1ST PREV QTR RANK	1ST PREV QTR LSC	2ND PREV QTR RANK	2ND PREV QTR LSC	3RD PREV QTR RANK	3RD PREV QTR LSC	SPEC INV	SPECIAL GFAE	CODING EXEMPT
46754	TELESCOPING L	0.004	C	1707	$287	2717	$78	1932	$247	1838	$291			
46755	CONTROL STICK	0.037	C	425	$2953	480	$2476	574	$2214	509	$2644			
46756	JACKSHAFT ASS	0.023	C	587	$1860	606	$1795	509	$2696 P	675	$1800			
4675?	DIFFERENTIAL	0.001	C	2831	$63	2262	$143	1859	$271	2411	$141			
46758	CONTROL ARM	0.007	C	1224	$553	1272	$518	1223	$658	1267	$644			
4675A	BOOM ASSEMBLY	0.108	C	150	$8621 P	119	$10821 P	98	$16674 P	84	$18600			
4675E	CONTROL ROD	0.007	C	1201	$574	1047	$723	1570	$395	1108	$801			
46760	BOOM COMPONEM	0.027	C	525	$2186	375	$3293	520	$2624	605	$2069			
46761	OUTER TUBE	0.000	C	3276	$28	2376	$125	2485	$124	2997	$56			
46762	INNER TUBE	0.002	C	2123	$175	3423	$19	2497	$121	2608	$107			
46763	SHOCK ABSORBE	0.016	C	P 746	$1264	556	$2043	562	$2323	579	$2183			
46764	ROLLER BRACKE	0.000	C	3506	$14	3027	$47	3474	$20	3612	$14			
46765	RING SPRING A	0.003	C	1821	$247	2275	$141	3682	$9	1983	$237			
46766	RUDDERVATOR	0.054	C	313	$4294	260	$5079 P	221	$7164	250	$6279			
46767	RUDDERVATOR L	0.008	C	1115	$668	1023	$754	788	$1364	707	$1693			
46768	RUDDERVATOR Q	0.028	C	520	$2222	662	$1546	685	$1666 P	469	$2946			
4676A	RUD LK GD ROL	0.014	C	823	$1102	788	$1174	760	$1431	609	$2052			
4676B	BOOM FORK ASS	0.017	C	699	$1360 P	361	$3527	688	$1659	1058	$859			
4676C	FITTING FWD P	0.000	C	3355	$21	3293	$27	3197	$38	3749	$7			
4676D	BOOM FORK SHA	0.000	C	3383	$19	2265	$143	3399	$24	3673	$9			
4676E	BOOM FORK THR	0.001	C	2900	$57	3312	$26	3247	$34	3638	$12			
4676F	BOOM FORK SHA	0.002	C	2297	$141	2078	$182	3222	$36	3034	$53			
4676G	TUBE WELD TEL	0.000	C	3643	$7	3745	$5	3212	$37	3718	$8			
4676H	SLIDING GLAND	0.041	C	387	$3253	605	$1796	564	$2297	396	$3646			
46771	NOZZLE ASSY	0.226	C	75	$17981	94	$13803	90	$17703 P	87	$18098			
46772	TAILCONE BOOM	0.076	C	230	$6058	674	$1504	593	$2073	672	$1807			
46773	SURGE BOOT	0.019	C	659	$1528	894	$940	754	$1445	795	$1409			
46774	SURGE BOOT LI	0.000	C	3177	$33	3588	$9	3869	$2	2719	$91			
46775	CABLE ATTACHM	0.002	C	2276	$144	1884	$233	2452	$131	2870	$72			
46776	TRAVEL STOP	0.001	C	2735	$74	2926	$56	2296	$158 P	1438	$509			
46777	SHOCK ABSORDO	0.021	C	619	$1697	882	$963	775	$1388	692	$1755			
46778	TELESCOPING D	0.004	C	1668	$302	989	$799	1437	$475	1406	$529			
4677A	BOOM NOZZLE I	0.001	C	2432	$116	2241	$147	1551	$408	1948	$247			
4677B	BALL UNIVERSA	0.013	C	873	$1001	930	$884	890	$1118	849	$1250			
4677C	PULLEY	0.003	C	1968	$206	2996	$51	1712	$321	3138	$44			
46780	A/R PUMP REGU	0.004	C	1578	$340	1564	$341	1445	$471	1864	$279			
46781	NOZZLE CK VAL	0.002	C	2094	$181	3152	$38	2870	$70	1801	$308			
46782	NOZZLE HEAD	0.032	C	467	$2580	705	$1401	506	$2710	641	$1923			
46783	FUEL DUMP ACT	0.019	C	660	$1520	1059	$714	897	$1103 P	603	$2071			
46784	CHAIN	0.003	C	1993	$202	2757	$73	2024	$216	2379	$147			
46785	CABLE	0.002	C	2321	$138	2314	$135	2616	$101	2134	$194			
46786	AZIMUTH DRUM	0.012	C	900	$955	815	$1096	1065	$835	766	$1505			
46787	ELEVATOR DRUM	0.004	C	1610	$329	1658	$300	2371	$146	2650	$102			
46788	FLEXIBLE COUP	0.004	C	1683	$294	1755	$266	1196	$685	1428	$514			

Figure 4. Sample K051.PN3L Report

Two exceptions were made in order to bring components with design differences between the KC-135 boom and the AARB into the analysis. These two exceptions--the signal coil amplifier and the azimuth control unit--will be more fully explained in the next section of this chapter.

The list of FLUs used in the analysis was finalized after the AARB analysis began. The selection of the KC-135 boom FLUs was based on either of the following criteria: (1) the components were major KC-135 boom logistics support cost contributors and had corresponding, but not identical, components on the AARB; or (2) the components were peculiar to either the KC-135 boom or the AARB and either were, or had the possibility of being major logistics resources consumers, respectively. In all, 15 FLUs were chosen for the KC-135 boom analysis, and 12 FLUs were chosen for the AARB analysis. The 15 KC-135 FLUs are listed in Table II, on page 71, and the AARB FLUs are discussed in Chapter IV.

<u>KC-135 Boom FLUs</u>

As indicated by the asterisk beside WUCs in Table II, 9 of the 15 FLUs included more than one WUC, NSN, or both; therefore, these were FLUs for which data could not be directly read from the data sources.

The peculiar aspects of these 9 FLUs are discussed in the following paragraphs.

Table II
KC-135 Boom FLUs

No.	WUC	FLUNOUN	NSN	No. of NSNs	Other WUCs
1	4676B*	Boom Fork Assy	1560-00-068-2535		4
2	46766	Ruddevators	1560-00-249-9370		
3	46794	Ruddevator Boost Units	1650-00-612-3748		
4	46768*	Ruddevator Quadrant Assy.	1560-00-789-2952	3	1
5	4676A*	Ruddevator Lock Roller Assy.	3120-00-555-4971	1	
6	51921*	Transmitters	6610-00-550-6913		2
7	46857	Elevation Control Unit	1680-00-659-0122		
8	4685A	Azimuth Control Unit	1680-00-545-5027		
9	46851*	Signal Coil Amplifier	1680-00-518-2991		2
10	46773	Surge Boots	1560-00-568-3469		
11	4676H*	Gland Seal	1560-00-713-2280		
12	46771*	Nozzle Assy.	1560-00-656-6170		5
13	46772*	Tailcone Assy.	1560-00-631-7598		2
14	46778*	Extension Drive Unit	1650-00-511-5280		3
15	46854	Telescope Control Unit	1680-00-658-9102		

* More than one WUC, NSN, or both in the FLU.

Boom Fork Assembly. The boom fork assembly is a diverse collection of components that in various ways attach to or are associated with the boom fork itself. Four of these components have unique WUCs; however, some repairs to the components are reported against the WUC for the boom fork and some repairs to the boom fork are reported against the other WUCs. Therefore, it was decided to consider all of the

parts as an assembly and as one FLU. The other four WUCs that were included in the boom fork assembly are (1)4676C, the forward pivot fitting; (2) 4676D, the boom fork shaft; (3) 4676E, the boom fork thrust plate; and (4) 4676F, the boom fork shaft nut.

Ruddevator Quadrant Assembly. The ruddevator quadrant assembly is another heterogeneous assortment of components. No major part in this collection has any notable failure rate except the ruddevator shaft bearings. However, the bearings are not a part that is peculiar to the KC-135. The bearings have no unique WUC so the work done on the bearings is always buried in the work done on other parts. In fact, only four specific parts located in the quadrant have repairs recorded against them. Therefore, it was decided to consider these four parts as an assembly and as one FLU. Since the work on these parts is reported against two WUCs, both were included in the FLU. The second WUC is 46767, the ruddevator quadrant lock sector assemblies. The four stock numbered parts are (1) 1560-00-789-2952 and 2953, the left and right ruddevator quadrant assemblies repsectively; and (2) 1560-00-766-9797 and 9798, the left and right ruddevator quadrant lock sector assemblies respectively.

Ruddevator Lock Roller Assembly. The ruddevator lock roller assembly consists of a small roller and a small bushing that, through a mechanical linkage to the ruddevator quadrant, cause the ruddevators to be locked in the streamlined position when the boom is stowed. These two small

parts which work together and are replaced together as a unit were considered as an assembly and as one FLU. Besides the NSN of the roller, which was listed in Table II, the NSN of the bushing is 3120-00-555-4972.

Transmitters. There are three identical transmitters on the boom system that operate instruments in the boom operator's station. Although the telescope, elevation and azimuth position transmitters are identical parts, each one had a different WUC. Their logistics support cost histories, however, are similar. Therefore, rather than making three separate FLUs, it was decided that the three transmitters would be treated as one FLU. Besides the WUC that is indicated in Table II, which was for the telescope position transmitter, WUCs 51923 and 51925, for the azimuth and elevation position transmitters repsectively, were included in the analysis.

Azimuth Control Unit. Although the azimuth control unit is not physically located on the boom, it was included in this analysis because there will not be an exact counterpart for it in the AARB. The function, however, will be present in the fly-by-wire control system of the AARB. Therefore, it was included to capture this design difference between the two booms.

Signal Coil Amplifier. The signal coil amplifier, although physically located in the tail of the aircraft, was included in the analysis because of the irregularities previously noted in WUC reporting. The signal coil system is

subject to many circuit discontinuities. These discontinuities frequently occur in the electrical system somewhere between the coil and the amplifier. However, this work is reported against either: (1) the WUC indicated in Table II, which is the WUC for the signal coil amplifier; (2) 46850, the WUC for the electrical system; or (3) 46856 the WUC for the signal coil. Furthermore, work on the coil is reported against the amplifier and the electrical system, and work on the amplifier is reported against the other two, etc. Therefore, in an attempt to capture as much of the information on these components as was possible, the three WUCs were combined into one FLU.

<u>Sliding Gland Seal</u>. As noted in the description of the boom, the sliding gland seal is a collection of rings, spacers, seals, and scrapers encased in a metal housing. No indication was found that the metal housing fails, but the other components of the seal are subject to leaks. Because of its position and function on the boom, when a leak develops and the seal has to be replaced, many man-hours are required to disassemble and then reassemble the boom. As a result, when one seal is removed all the seals are changed. All of these expendable parts are contained in a sliding gland seal kit. Therefore, it was felt that the kit represents a valid FLU, and the work associated with putting in a new seal kit adequately represents the work reported against the WUC.

Nozzle Assembly. There are five components of the nozzle assembly that have unique WUCs. Work done on the components is sometimes reported against the WUCs of the components. Sometimes it is reported against the WUC of the nozzle assembly itself. Therefore, in order to capture as much of the information as possible, the other five WUCs were included in this FLU. The other five WUCs are (1) 4677A, the housing assembly; (2) 4677B, the nozzle universal ball; (3) 46781, the nozzle check valve; (4) 46782, the nozzle (head); and (5) 46792, the boom nozzle sleeve and shaft.

Tailcone Assembly. The tailcone assembly includes three WUCs. Two other WUCs were included in this FLU for the same reasons that were given in the discussion of the nozzle assembly. The other two WUCs are (1) 46783, the fuel dump actuator and (2) 46798, the dump actuator cam guides.

Extension Drive Unit. The extension drive unit includes a gearbox, a hydraulic motor, and a drive chain and cable, each with a unique work unit code. It was decided to combine all four parts of this assembly under the WUC for the gearbox, or extension drive unit, as a single functional FLU. The other three WUCs are (1) 46811, the motor; (2) 46784, the chain; and (3) 46785, the cable.

This completes the discussion of the FLUs that were selected for the KC-135 boom logistics support cost analysis. The next section of this chapter describes the methodology used to extract values from existing data systems for the variables used in the Boom Model.

Determination of Values for KC-135 Variables

In the process of determining values for the Boom Model variables, many data products from Air Force maintenance data collection systems were evaluated. Useful data was found in some of the products and not in others. All of the Boom Model variables, except those government-furnished standard variables which had constant values, are discussed in the following sections. The data sources used in determining the values for the variables are briefly discussed, and annotated samples of the data products are shown when they enhance the discussion. Also, the irregularities in the calculation of the values for the variables for some of the FLUs are discussed. For more information on specific data products the reader may turn to Appendix H.

Determination of values for weapon system variables. The weapon system variables are those variables that describe the operational scenario of the KC-135 tanker force. The values for these variables were based upon the force deployment and activity levels of today. The values for those nonstandard weapon system variables are shown in Table III.

Table III
Values for KC-135 Weapon System Variables*

VARIABLE	BRIEF DESCRIPTION	VALUE	SOURCE** OF DATA
TFFH	Total Force Flying Hours	2,400,000	R
PFFH	Peak Force Flying Hours	60,000	R
PIUP	Program Inventory Usage Period	10	R
M	Number of Operational Bases	36	G033
OS	Fraction of Force Deployed Overseas	.071	G033
EBO	Standard for Expected Backorders	.10	R
NSYS	Number of Systems in Weapon System	1	R

* Only those parameters that are true variables are presented here. Those variables that have standard values that do not vary between weapon systems are not presented here.

** Data Sources and Codes: G033BQI3B G033; Researchers R

EBO. The standard established for the expected number of backorders for the weapon system (EBO) was used in the calculation of the costs of base and depot repair pipeline FLU spares. For the KC-135 boom system, these costs are sunk costs so EBO was not applicable.

M. The number of bases that provide intermediate level (base shop) maintenance and support (M) was taken from the unclassified G033BQI3B, "Aerospace Vehicle Inventory by Station (Within M/D/S)," report. Within each aircraft mission/design/series (M/D/S), this report lists the number of aircraft at each location, both in the continental United States and overseas (18).

NSYS. The number of systems within the weapon system (NSYS) was chosen by the researchers. Since the purpose of the research was to estimate the differential logistics support costs between the two boom systems, the number of systems was limited to one. No insight would have been gained by considering the electrical, hydraulic, fuel and control systems separately. Such a breakdown would be more useful for analyzing an entire aircraft or another type of major weapon system. The effect of using additional systems mainly affects support concepts such as system peculiar support equipment or system support facilities.

OS. The fraction of the total weapon system force deployed overseas (OS) was calculated from the same information in the GO33BQI3B report that was used in determining the value for M.

PFFH. The peak force flying hours (PFFH), or the maximum number of hours to be flown by the force in any one month period, was arbitrarily assumed by the researchers to be three times the normal monthly activity level. The normal monthly activity level was calculated as 1/120 of the total force flying hours (TFFH) for ten years.

PIUP. The program inventory usage period (PIUP) or operational service life of the system was arbitrarily given a value of ten years by the researchers. A different value would have changed the total logistics support cost figure of merit in a nearly linear fashion, since most of the costs counted are recurring costs.

TFFH. The value for the expected total force flying hours (TFFH) over the program inventory usage period was calculated by the researchers by taking a representative annual flying hour figure and multiplying it by ten. The annual figure of 240,000 is representative of the figures obtained from item managers of tanker peculiar boom components, and is also reasonably close to the activity level indicated in D056B5006, "Maintenance, Manhours and Aborts by Work Unit Code." Reasonable figures for the expected activity level are obtainable from any of several sources.

The D056B5006 report is a data product that lists, by WUC, the number of hours that were flown in each of the six months prior to the end of the reporting period, the number of component failures, the mean time between failures (MTBF), and several categories of maintenance man-hours. This report is more fully explained and an example is shown on page 99.

Determination of values for system variables. The system variables are those variables that are peculiar to the boom system being studied, but they are not distributed to the FLUs within the system. The values for the nonstandard system variables are shown in Table IV.

Table IV
Values for KC-135 Boom System Variables*

VARIABLE	BRIEF DESCRIPTION	VALUE	SOURCE** OF DATA
SHQ	Quarterly Scheduled Man-Hours	8,200	R
SECOST	Total Cost of New Support Equipment	0	R
N	Number of FLUs in the System	15	R
FB	Cost of New Base Facilities	0	R
FD	Cost of New Depot Facilities	0	R
H	Number of Pages of New Technical Data	0	R
TCB	Cost to Train Inflight Refueling Specialist	6,931	R
TCA	Cost to Train Avionics Specialist	17,146	R
MENB	Number of Inflight Refueling Specialists	5	R
MENA	Number of Avionics Specialists	0	R
KTYP	System Indicator	135	R
TE	Total Cost of New Training Equipment	0	R

* System variable with nonstandard values are presented in this chart.

** R indicates that values were estimated or assigned by researchers.

FB and FD. The costs of new base and depot facilities (FB and FD repsectively) were given values of zero by the researchers. It was assumed that the existing facilities were adequate to support the KC-135 boom system for the next ten years. Therefore no new facilities would be required.

H. Much of the same technical data required for repair of the boom system at the depot was also found to be maintained at the base level. Therefore, rather than

arbitrarily separate the two types, it was decided to combine the number of pages required at base and depot levels into a single term (H) representing the total number of pages of technical orders and special repair instructions required to maintain the system. Since these documents are in existence and will continue in use for the foreseeable future, this variable was given a value of zero by the researchers for the KC-135 analysis.

KTYP. KTYP was a dummy variable that was used in the Boom Model computer program. It caused some of the equations to be calculated differently, depending on whether the system that was being considered was the KC-135 boom or the AARB. This variable allowed the sunk costs of spares and initial training to be eliminated from the KC-135 logistics support cost figure of merit. For this analysis, the value "135" was assigned to this variable.

MENB. The number of men required to man a base inflight refueling maintenance shop (MENB) was assumed to be 5. This value was not meant as a verifiable figure but as a reasonable representation of the situation the researchers found at most field units.

MENA. The number of additional avionics specialists that would have to be trained to maintain the fly-by-wire system in the AARB (MENA) had no significance in the KC-135 analysis. Therefore, it was given a value of zero by the researchers.

N. The number of FLUs in the KC-135 boom system (N) that were included in the analysis was 15. These 15 FLUs are listed in Table II (page 71); they are also listed in Table V on page 85 and Table VI on page 87.

SECOST. The total cost of new support equipment required to maintain the KC-135 boom system (SECOST) was given a value of zero by the researchers. It was assumed that the presently owned support equipment would continue in use for the additional ten year service life. The present support equipment for the boom consists of trailers designed to support and transport the boom and a set of special tools and test equipment.

It seems reasonable to assume that most conceivable problems which may affect the presently owned support equipment would be repaired locally and that the magnitude of the cost of operation of this equipment would be very small in comparison with the total system cost.

SHQ. Scheduled maintenance hours were taken from the D056B5006 report, "Maintenance Actions, Man-Hours, and Aborts by Work Unit Code." Scheduled man-hours in this report include servicing, preflight, postflight, and phased inspections, time compliance technical orders and a few other lesser categories listed in T.O. 1C-135(K)A-06 (77:III-01). The scheduled man-hours, shown on the D056B5006 report for the six month period, were divided by two to get a quarterly average and then summed over all of the WUCs included in the FLUs. This value was assumed, by the researchers, to represent the

average quarterly number of man-hours spent on scheduled maintenance activities (SHQ).

TCB. The cost of training one base level inflight refueling specialist to the "five level" or fully qualified status (TCB) was obtained from Air Training Command Headquarters. The costs of technical school, local Field Training Detachment classes, shop instruction, and on-the-job training for approximately one year were included.

TCA. The cost of training one avionics specialist to maintain the fly-by-wire system in the AARB (TCA) had no significance in the KC-135 analysis. (See KTYP on page 81.)

TE. The total cost of new training equipment (TE) was assumed by the researchers, to be zero. There are no base level training aids and the existing depot level training aids are sunk costs for this analysis.

<u>Determination of values for FLU variables</u>. The FLU variables are those variables that reflect the design parameters and the logistics support cost aspects of the individual components. Necessarily, the values for all the variables had to be obtained separately for each FLU. Many different data sources were used for the different variables, and in some cases, because of the unique characteristics of peculiar FLUs, different data sources were used to obtain values for the same variables. Throughout this section annotated sample data products and calculations show how the values for the variables were obtained. For continuity, the same FLU--the tailcone assembly--was used for all but the last calculation.

The equations used in this chapter for calculating values for specific variables are not to be confused with the Boom Model equations explained in Chapter II.

Table V shows the 15 KC-135 boom system FLUs that were used in the logistics support cost analysis and the data sources for each of the "true" FLU variables--those variables that actually differed between FLUs. The table also shows, by FLU, which variables had some peculiar aspect to their calculation and which were reparable.

Table V
KC-135 Boom FLUs, Variables, and Data Sources[1]

FLU NAME \ VARIABLE	QPA	UC	MTBF	RIP	RTS	NRTS	COND	BMC	DMX	IMH	RMH	BMH	WEIGHT	DRCT	REPAR-ABLE
Boom Fork Assy.	* -4	* COS	* 6LOG	* 5LOG	* COS	* COS	* COS	* PN7L	* COS	* PN7L	* PN7L	* 5LOG	* PN8L	* IM	Y
Ruddevators	* -4	* COS	* 6LOG	* 5LOG	* COS	* COS	* COS	* PN7L	* COS	* PN7L	* PN7L	* 5LOG	* PN8L	* IM	Y
Ruddevator Boost Unit	* -4	* COS	* 6LOG	* 5LOG	* COS	* COS	* COS	* PN7L	* COS	* PN7L	* PN7L	* 5LOG	* PN8L	* IM	Y
Ruddevator Quadrant Assy.	** -4	** IM	* 6LOG	* 5LOG	** R	** R	** R	** PN7L	** R	** PN7L	** PN7L	** 5LOG	** DS	** R	N
Ruddevator Lock Roller Assy.	* -4	* IM	* 6LOG	* 5LOG	** R	** R	** R	** R	** R	* PN7L	* PN7L	* 5LOG	** DS	** R	N
Transmitters	* -4	* COS	* 6LOG	* 5LOG	** R	** R	** R	** R	** R	* PN7L	* PN7L	* 5LOG	* PN8L	** R	N
Elevation Control Unit	* -4	* COS	* 6LOG	* 5LOG	* COS	* COS	* COS	* PN7L	* COS	* PN7L	* PN7L	* 5LOG	* PN8L	** IM	Y
Azimuth Control Unit	* -4	* COS	* 6LOG	* 5LOG	* COS	* COS	* COS	* PN7L	* COS	* PN7L	* PN7L	* 5LOG	* PN8L	* IM	Y
Signal Coil Amplifier	* -4	* IM	* 6LOG	* 5LOG	** R	** R	** R	** PN7L	** R	* PN7L	* PN7L	* 5LOG	* DS	** R	N
Surge Boots	* -4	* IM	* 6LOG	* 5LOG	** R	** R	** R	** R	** R	* PN7L	* PN7L	* 5LOG	* DS	** R	N
Gland Seal	* -4	* IM	* 6LOG	* 5LOG	** R	** R	** R	** R	** R	* PN7L	* PN7L	* 5LOG	* DS	** R	N
Nozzle Assy.	* -4	* COS	* 6LOG	* 5LOG	* COS	* COS	* COS	* PN7L	* COS	* PN7L	* PN7L	* 5LOG	* PN8L	* IM	Y
Tailcone Assy.	* -4	* COS	* 6LOG	* 5LOG	* COS	* COS	* COS	* PN7L	* COS	* PN7L	* PN7L	* 5LOG	* PN8L	* IM	Y
Extension Drive Unit	* -4	* COS	* 6LOG	* 5LOG	* COS	* COS	* COS	* PN7L	* COS	* PN7L	* PN7L	* 5LOG	* PN8L	* IM	Y
Telescope Control Unit	* -4	* COS	* 6LOG	* 5LOG	* COS	* COS	* COS	* PN7L	* COS	* PN7L	* PN7L	* 5LOG	* PN8L	* IM	Y

[1] Refer to Legend on page 86.

Table V (Continued)
Legend

Sources:	Researchers		R
	G033BQI3B		G033
	T.O. 1C-135(K)A-4		-4
	Item Manager		IM
	K051.PN7L		PN7L
	K051.PN8L		PN8L
	D056B5505		5LOG
	D056B5006		6LOG
	COSPERANK		COS
	Depot Shipping		DS
Method of Computation:		Normal	*
		Not Normal	**
Reparable Item:		Yes	Y
		No	N

NOTE: Only the parameters which were truly variables are presented here. The parameters omitted from the table did not vary between FLUs. They include weapon system and system level variables, standard value FLU parameters and FLU variables which were assigned the same value for all FLUs.

Table VI on page 87 shows the FLUs and the values for all of the FLU variables. For comparative purposes Appendix D also shows the values for the AARB variables.

BMC. The variable BMC was used in the original LSC Model to include the costs of material and labor expended in the repair of subassemblies below the FLU level. This variable is used in equation C_3 to compute the cost of off-equipment maintenance. BMC is defined in the Model Handbook as "the average cost per failure for a FLU repaired at base level for stockage and repair of lower level assemblies expressed as a fraction of the FLU unit cost (UC) [51:2-6]."

AD-A032 274 AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OHIO SCH--ETC F/G 1/2
A LOGISTICS SUPPORT COST ANALYSIS OF THE ADVANCED AERIAL REFUEL--ETC(U)
SEP 76 R T JEFFREYS, C L SEARS

UNCLASSIFIED GSM/SM/76S-13 NL

2 OF 3
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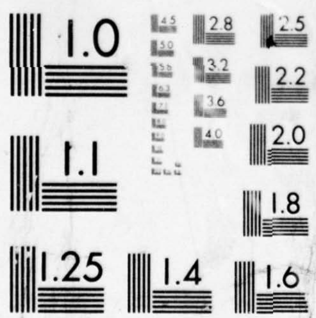
1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
5.0

Table VI
Values for KC-135 Boom FLU Variables

FLU NAME \ VARIABLES	QPA	UC	MTBF	RIP	RTS	NRTS	COND	BMC	DMX	IMH	RMH	BMH	W	DRCT
Boom Fork Assembly	1	1102.56	8836	.92	.58	.40	.02	.021	794.84	1.4	6.7	2.6	8	2.25
Ruddevators	2	3804.31	2754	.87	.50	.50	0	.009	1509.51	1.3	2.5	5.5	151	2.25
Ruddevator Boost Units	2	3359.65	1844	.87	.74	.26	0	.009	716.25	1.9	6.0	3.9	20	2.25
Ruddevator Quadrant Assembly	4	364.56	4158	.82	0	0	1.00	.108	0	2.7	8.5	2.5	2.25	0
Ruddevator Lock Roller Assembly	1	3.53	459	.45	0	0	1.00	0	0	.7	1.1	1.4	.25	0
Transmitters	3	121.60	2272	.72	0	0	1.00	0	0	3.5	4.0	1.1	2	0
Elevation Control Unit	1	2022.14	1178	.90	.29	.59	.12	.025	368.67	3.4	4.9	3.6	8	1.84
Azimuth Control Unit	1	239.15	1537	.92	.44	.41	.15	.073	155.00	1.1	4.8	3.7	3	1.84
Signal Coil Amplifier	1	175.00	339	.92	0	0	1.00	.180	0	2.3	3.0	2.4	.75	0
Surge Boots	2	496.00	5891	.88	0	0	1.00	0	0	1.6	6.7	6.3	31	0
Gland Seal	1	41.60	2525	.92	0	0	1.00	0	0	2.9	14.2	4.3	1	0
Nozzle Assembly	1	7273.60	202	.83	.79	.21	0	.004	499.20	1.5	3.5	6.0	31.5	2.25
Tailcone Assembly	1	12035.00	862	.83	.35	.63	.02	.004	4782.97	1.7	3.7	8.2	50	2.25
Exstension Drive Unit	1	4736.00	1657	.92	.44	.56	0	.005	6314.67	1.6	3.6	4.0	49	1.84
Telescope Control Unit	1	8450.00	7573	.89	.14	.86	0	.007	375.55	4.2	7.4	2.0	9	2.25

The researchers interviewed several users of the LSC Model, and all of these persons agreed that there was no widely accepted method of calculating BMC--each used subjective estimates. This was fine for developing systems, there being no real alternative due to the lack of historical data. But for this study, involving an ongoing system, the researchers felt that a more objective method should be found.

The method that was developed departed somewhat from the concept defined in the Model Handbook. The K051.PN7L report, "Maintenance Action Summary," was used as the source of data. The K051.PN7L report is another IROS data product that shows within each WUC: (1) the NSNs of components that were repaired; (2) the number of units under each entry that were repaired, both on- and off-equipment, with the average number of man-hours per repair; and (3) the number of units repaired and the average number of man-hours per repair for those actions that were recorded only against the WUC but not against any specific stock number within that WUC. These actions were displayed under the entry "999999999999999." Figure 5 on page 90 shows a sample K051.PN7L report.

BMC was calculated in the following manner:

$$BMC = \frac{\left[\sum_{j=1}^{J} TFMH_j - MCMH\right](BLR)}{(UC)\sum_{j=1}^{J} UOF_j}$$

where J = number of WUCs included in the FLU

TFMH = total off-equipment man-hours in all entries for all WUCs included in a FLU

MCMH = man-hours for the major stock numbered component of a FLU

BLR = base labor rate ($13.03/hr)

UC = unit cost of the FLU

UOF = total number of units (maintenance actions) represented by TFMH.

This method does not include the stockage costs of lower level parts because only man-hours were used in its derivation; however, the omission of such costs was felt to be worth the degree of objectivity gained. Since such additional costs are as elusive for new as for existing systems, it was felt to be preferable to leave them out of the analysis.

For the tailcone assembly (WUCs 46772, 46783, and 46798),

$$\mathrm{BMC} = \frac{[(165.7 + 264.5 + 35.0) - 41.0](13.03)}{(33 + 129 + 25)(12{,}035.00)} = .004$$

The numbers used in this calculation, for WUC 46772, are highlighted by the dark outline in Figure 5 on page 90.

The determination of BMC values for four FLUs required special attention. These four FLUs, the ruddevator lock roller assembly, the transmitters, the surge boots, and the gland seal were expendable--nonreparable--items that had no lower level components. Therefore, BMC was given a value of zero by the researchers for these FLUs.

E 16
WEAPON SYSTEM KC135A OCALC MAINTENANCE ACTION SUMMARY RCS LOG-MMO(Q)7215 K051.PN7L PAGE 695
AFM 65-110/66-1 DATA AS OF 75 DEC DATE PROCESSED 76 FEB 01

			ON EQUIPMENT						OFF EQUIPMENT									
			REPAIRED		EXPENDED		TO SHOP		NRTS		CONDEMNED		NO DEFECT		OTHER		ABORTS	
MUC	NSN	NOUN	UNIT	AV MH	UNIT	AV MH	UNIT	AV MH	UNIT	AV MH	UNIT	AV MH	UNIT	AV MH	UNIT	AV MH	BFA	IFA
46771	1560006793639FH	NOZZLE ASSEMBLY** NO AFM 66-1 DATA **																
	1560009964523FL	TUBE, NOZZLE ER** NO AFM 66-1 DATA **																
	1680005182991	AMPLIFIER,ELECT** NO AFM 66-1 DATA **																
	1680007588152	PUMP,FUEL TRANS** NO AFM 66-1 DATA **																
	999999999999999	NOZZLE ASSY																
		FAILURE	60	1.3	0	0.0	184	3.4	1	2.5	0	0.0			14	7.5	0	0
		OTHER	1144	1.5	0	0.0	1	7.0	0	0.0	0	0.0	0	0.0	0	0.0		
46772	1560006317598FL	CONE ASSEMBLY,B																
		FAILURE	0	0.0	0	0.0	5	6.7	6	0.9	0	0.0			8	4.2	0	0
		OTHER	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	2.0		
	1560007005758FL	** NO BASELINE DATA, MASTER RECORD ESTABLISHED, M-H USED **																
		OTHER	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0		
	999999999999999	TAILCONE BOOM																
		FAILURE	1	3.0	0	0.0	11	5.6	0	0.0	0	0.0			2	14.8	0	0
		OTHER	45	2.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0		
46773	999999999999999	SURGE BOOT																
		FAILURE	3	1.4	0	0.0	24	6.7	0	0.0	0	0.0			0	0.0	0	0
		OTHER	95	1.6	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	11.5		
46774	999999999999999	SURGE BOOT LINE																
		FAILURE	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0			1	7.0	0	0

IMH

RMH

BMC

Figure 5. Sample K051.PN7L Report

BMH. The average man-hours required to perform base level off-equipment (shop) maintenance (BMH) was obtained from the D056B5505, "Summarized Maintenance Actions by Work Unit Codes." Part II of this report, entitled "Shop Actions," contains the number of failed units that were repaired during the period, and the total number of hours that were reported for these repairs. BMH was only calculated for the primary WUC because the variable BMC corrects for the repair of lower level assemblies and components. It was assumed that BMH includes the man-hours for in-shop troubleshooting, repairing, and testing.

BMH was calculated in the following manner:

$$BMH = \frac{TFMH}{TFU}$$

where TFMH = total off-equipment man-hours for the primary WUC

TFU = total off-equipment units (failures) for the primary WUC.

For the tailcone assembly (WUC 46772),

$$BMH = \frac{328.4 \text{ hours}}{40 \text{ failures}} = 8.2 \text{ hrs/failure.}$$

Figure 6 on page 92 shows a sample D056B5505 report with the numbers used in the tailcone assembly calculation highlighted.

The only FLU that required special treatment was the ruddevator quadrant assembly. In this case, the man-hours and units from both WUCs were used in the calculation because each WUC contained some of the major components.

OCALC-ACF SUMMARIZED MAINTENANCE ACTIONS FOR SELECTED WORK UNIT CODES PAGE 278
KC135A 46772 MC6037 PERIOD ENDING 76 MAR 31 FORMERLY 5-LOG-K261 PCN D056B5505
WUC 46772 TAILCONE BOOM CAT IND C RCS LOG-MMO<AR>7169

PART II - SHOP ACTIONS

FSC 1560	P/N 15-95803-40	UNITS	1	FSC 1560	P/N 30-4694-17	UNITS	
FSC 1560	P/N 5-96330	UNITS	1	FSC 1560	P/N 5-96330-287	UNITS	1
FSC 1560	P/N 50-46494-18	UNITS	1	FSC 1560	P/N 50-4694-1	UNITS	3
FSC 1560	P/N 50-4694-17	UNITS	1	FSC 1560	P/N 50-4697-18	UNITS	
FSC 1560	P/N 50-9694-17	UNITS	1	FSC 1560	P/N 50469418	UNITS	
FSC 1560	P/N 50469420	UNITS	1				

--HOW MALFUNCTION--- CODE	NOUN	REPAIR AFG UNITS	HOURS	ADJUST KL UNITS	HOURS	CLN/TEST/CRSN VXZ UNITS	HOURS	SRVCBLE BJ UNITS	HOURS	NRTS & CONDEMNED 1	2-6	7-8	9	HOURS	TOTAL UNITS	HOURS	DELAYED CDMN UNITS	HOURS
190	CRACKED	4	42.0		.0		.0		.0					.5	4	42.5		.0
381	LEAKING	1	16.0		.0		.0		.0					.0	1	16.0		.0
780	BENT	1	27.1		.0		.0		.0	2				1.5	3	28.6		.0
800	NC C FAC MAIN		.0		.0		.0		.0					.0		.0	1	5.0
947	TCRN		.0		.0		.0		.0	1				.3	1	.3		.0
	TCTAL	6	85.1		.0		.0		.0	3				2.3	9	87.4	1	5.0

BASE	NOUN	REPAIR UNITS	HOURS	ADJUST UNITS	HOURS	CLN UNITS	HOURS	SRVCBLE UNITS	HOURS	NRTS 1	2-6	7-8	9	HOURS	TOTAL UNITS	HOURS	DELAYED UNITS	HOURS
BAEY	BEALE 15AF CALI	1	8.0		.0		.0		.0					.0	1	8.0		.0
DESR	CASTLE 2AF CAL	3	34.0		.0		.0		.0					.0	3	34.0		.0
FNWZ	DYESS 2AF TEX		.0		.0		.0		.0					.5		.5		.0
FXBM	ELSWRTH 15AF SC		.0		.0		.0		.0	1				1.0	1	1.0		.0
JFSD	GRN FRK 15AF ND		.0		.0		.0		.0	1				.5	1	.5		.0
NLZG	LOCBURN AFB OHO		.0		.0		.0		.0					.0		.0	1	5.0
NRCH	LORING 2AF ME	1	8.0		.0		.0		.0					.0	1	8.0		.0
PCZP	MARCH 15AF CALI		8.0		.0		.0		.0					.0		8.0		.0
PLXL	MATHER AFB CALF		21.5		.0		.0		.0					.0		21.5		.0
QJVF	MINOT 15AF ND		.0		.0		.0		.0	1				.3	1	.3		.0
VKAG	SEYM JHN AFB NC		3.6		.0		.0		.0					.0		3.6		.0
ZJXD	WRTSMTH2AF MICH	1	2.0		.0		.0		.0					.0	1	2.0		.0
	TCTAL	6	85.1		.0		.0		.0	3				2.3	9	87.4	1	5.0

	REPAIR AFG UNITS	HOURS	ADJUST KL UNITS	HOURS	CLN/TEST/CRSN VXZ UNITS	HOURS	SRVCBLE BJ UNITS	HOURS	NRTS & CONDEMNED 1	2-6	7-8	9	HOURS	TOTAL UNITS	HOURS
WUC TCTAL	22	303.3		.0		.0		.0	17		1		25.1	40	328.4

Figure 6. Sample D056B5505 Report--Part II

COND, NRTS, and RTS. The fractions of removed, reparable FLUs that were condemned at base level (COND), determined to be not reparable this station (NRTS), and determined to be reparable this station (RTS) were calculated from data in the COSPERANK report. The values of these variables for nonreparable FLUs were assigned by the researchers.

The COSPERANK system is a logistics support cost system that was developed by Mr. Jimmy D. Bias, Oklahoma City Air Logistics Center/MMP. This system is based on the D041, "Recoverable Consumption Item Requirements System" and therefore includes only reparable items. For more information on COSPERANK see Appendix H.

An item, once it is removed from the aircraft, is either repaired, condemned, or declared "not reparable this station" and sent to the depot for overhaul. Therefore, the fractions for COND, NRTS, and RTS always sum to one.

For reparable items, the value for NRTS was read directly from the COSPERANK printout. A sample printout for the tailcone assembly is shown in Figure 7 on page 94. The value for COND was calculated from the same printout in the following manner:

$$\text{COND} = \frac{\text{BCOND}}{\sum_{j=5}^{8} \text{BRG}_j}$$

```
NSN      1560006317598

NOUN     TAILCONE
OIALC  MMC  ITEM MGR CODE  TF
PRICE        12035.00
REPRCOST      684.00
NRTSX 63
BRGS BY QTR - 2 YRS
     17       12        15        10        13        12        17        12
     TOTAL BRGS         108.
PROG.HRS BY QTR - 2 YRS
    507      600       648       667       634       553       610       580
     TOTAL HRS        4799.
BASE COND BY MONTH - 1 YR
      1        0         0         0         0         0
      0        0         0         0         0         0
     TOTAL BASE COND             1.
NRTS BY MONTH - 1 YR
      4        3         4         3         2         2
      3        4         3         3         3         2
     TOTAL NRTS         36.
DEPOT SB&CR COND BY MONTH - 1 YR
      2        2         1         1         1         0
      0        0         0         2         2         2
    TOTAL SB&CR COND            13.
MTBD BY QTR
    2982.      5000.       4320.      6670.
    4377.      4608.       3588.      4833.
     AVG MTBD        4444.
DEPOT COST      172187.
TOTAL ESTIMATED COST       233355.
APPLICATIONS, QPA
 EC135A           1
 EC135C           1
 KC135A           1
1680001095725FL   1
1680001095730FL   1
TOTAL APPLICATIONS          5.
```

Figure 7. Sample COSPERANK Printout

where BCOND = the number of FLUs condemned at base level

BRG = the number of base reparable generations (failures) in the last year--each of the last four quarters.

RTS then was calculated in the following manner:

$$RTS = 1.00 - (NRTS+COND).$$

For the tailcone assembly, NRTS was .63, COND was calculated as 1/54 = .02, and RTS was calculated as 1.00 - (.63+.02) = .35. The numbers used in these calculations are highlighted in Figure 7 on page 94.

There are six FLUs that required a different treatment. These six FLUs are (1) the ruddevator quadrant assembly, (2) the ruddevator lock roller assembly, (3) the transmitters, (4) the signal coil amplifier, (5) the surge boots, and (6) the gland seal. All are nonreparable items. For these items a COND value of 1.00 was assigned by the researchers in order to pick up the stockage costs that are associated with these "throw away" FLUs. Consequently, the NRTS and RTS variables were assigned values of zero. Technically speaking, expendable items are not considered "condemned," even when discarded. A more logical method to treat these costs was not found, however, so this method was adopted, even though it meant that the costs of on-equipment and off-equipment maintenance associated with these FLUs were lost because of NRTS and RTS having values of zero in the computations (see equations C_2 and C_3 on pages 34 and 37.

DMX. As described in Chapter II, all depot costs were considered to be included in the average cost of depot maintenance (DMX). This factor includes labor, material, and overhead as well as an allowance for depot condemnations. Therefore, separate consideration of depot support equipment, training, labor and material used in depot repair was

unnecessary. This change also resulted in considerable simplification of the model and probably improved its usefulness and accuracy by shifting to an obtainable, auditable value for depot maintenance rather than using estimated values. Such a change was made possible by the fact that depot maintenance figures are available on reparable FLUs, even when the actual work is done at the depot rather than by a contractor. These figures were computed from data contained in the COSPERANK report.

DMX was calculated in the following manner:

$$DMX = \frac{DC}{TNRTS}$$

where DC = the depot cost of the FLU repair

TNRTS = the total number of NRTS FLUs (failures) for one year.

For the tailcone assembly,

$$DMX = \frac{\$172{,}187}{36 \text{ failures}} = \$4782.97 \text{ per failure}$$

The numbers used in the calculation are highlighted in Figure 7 on page 94.

Again, a special computation was required for the six nonreparable FLUs. When failures of these FLUs occur, they are not sent to the depot for repairs; therefore, a DMX value of zero was assigned to these FLUs by the researchers.

DRCT. This variable represents the average length of time it takes to repair a FLU which is sent to the depot or to a contractor for repair including transportation and

handling time. It is the average time from removal of the FLU until it is placed in the supply system as a usable part. If the FLU is repaired at the depot the value is 1.84 months, and if the repair is done by a contractor the value is 2.25 months. For the six expendable FLUs, a value of zero was assigned by the researchers. The repair locations of the FLUs were obtained from the item managers.

IMH. The values for the average number of hours that are required to repair failed FLUs in-place on the aircraft--on-equipment maintenance--were taken from the K051.PN7L report. The column, "Repaired," under the heading, "On-Equipment," corresponds to IMH. It was assumed that IMH included the man-hours associated with accessing, troubleshooting, repairing, and testing the FLU. The calculation was based on a weighted average repair time for all entries in each WUC that was included in the FLU.

IMH was calculated in the following manner:

$$IMH = \frac{\sum_{j=1}^{J} RPMH_j}{\sum_{j=1}^{J} URN_j}$$

where J = the number of WUCs included in the FLU

RPMH = the total number of man-hours in the "repaired" column

URN = the total number of failed units in the "repaired" column.

For the tailcone assembly (WUCs 46772, 46783, and 46798),

$$IMH = \frac{115.5 + 173.7 + 149.4}{46 + 108 + 108} = 1.7 \text{ hours/failure.}$$

The units and man-hours used in this calculation are highlighted in the sample data product in Figure 5 on page 90.

RMH. The values for the average number of man-hours to troubleshoot, remove and replace failed FLUs (RMH) were calculated from the K051.PN7L report in the same manner that values for IMH were calculated. This variable corresponds to the "To Shop" column under the heading, "On-Equipment." It was assumed that RMH included the man-hours associated with gaining access to the FLU.

RMH was calculated in the following manner:

$$RMH = \frac{\sum_{j=1}^{J} TSMH_j}{\sum_{j=1}^{J} USN}$$

where J = the number of WUCs included in the FLU

$TSMH$ = the total number of man-hours in the "To Shop" column for each WUC

USN = the total number of units (failures) in the "To Shop" column for each WUC.

For the tailcone assembly (WUCs 46772, 46783, and 46798),

$$RMH = \frac{95.1 + 49.0 + 35.0}{16 + 7 + 25} = 3.7 \text{ hours/failure.}$$

The "To Shop" column, fcr WUC 46772, is highlighted in Figure 5 on page 90.

K. The number of pieces of new support equipment that are required for the repair of a given FLU was given a value of zero by the researchers. Since K was implicitly included in the value of the variable, SECOST, which was zero for the KC-135 boom, the value of K for each FLU had to be zero also. The value of K did not vary between FLUs and it was not listed in Tables V and VI with the other FLU variables.

MTBF. The values for the mean flying time between failures (MTBF) were obtained from the D056B5006 report. In those cases where the FLU was comprised of a single WUC, it was possible to read the MTBF directly from the report. A sample D056B5006 report is shown in Figure 8 on page 100.

For those FLUs which included more than one WUC, the MTBF was calculated in the following manner:

$$\text{MTBF} = \frac{(\text{SOT})(\text{QPA})}{\sum_{j=1}^{J} F_j}$$

where J = the number of WUCs included in the FLU

SOT = the six months operating time in hours

QPA = the number of identical FLUs in the system

F = the total number of failures.

It was assumed for this research study that operating hours and flying hours were synonomous.

For the tailcone assembly (WUCs 46772, 46783, and 46798),

$$\text{IMH} = \frac{115.5 + 173.7 + 149.4}{46 + 108 + 108} = 1.7 \text{ hours/failure.}$$

The units and man-hours used in this calculation are highlighted in the sample data product in Figure 5 on page 90.

RMH. The values for the average number of man-hours to troubleshoot, remove and replace failed FLUs (RMH) were calculated from the K051.PN7L report in the same manner that values for IMH were calculated. This variable corresponds to the "To Shop" column under the heading, "On-Equipment." It was assumed that RMH included the man-hours associated with gaining access to the FLU.

RMH was calculated in the following manner:

$$\text{RMH} = \frac{\sum_{j=1}^{J} \text{TSMH}_j}{\sum_{j=1}^{J} \text{USN}}$$

where J = the number of WUCs included in the FLU

TSMH = the total number of man-hours in the "To Shop" column for each WUC

USN = the total number of units (failures) in the "To Shop" column for each WUC.

For the tailcone assembly (WUCs 46772, 46783, and 46798),

$$\text{RMH} = \frac{95.1 + 49.0 + 35.0}{16 + 7 + 25} = 3.7 \text{ hours/failure.}$$

The "To Shop" column, for WUC 46772, is highlighted in Figure 5 on page 90.

K. The number of pieces of new support equipment that are required for the repair of a given FLU was given a value of zero by the researchers. Since K was implicitly included in the value of the variable, SECOST, which was zero for the KC-135 boom, the value of K for each FLU had to be zero also. The value of K did not vary between FLUs and it was not listed in Tables V and VI with the other FLU variables.

MTBF. The values for the mean flying time between failures (MTBF) were obtained from the D056B5006 report. In those cases where the FLU was comprised of a single WUC, it was possible to read the MTBF directly from the report. A sample D056B5006 report is shown in Figure 8 on page 100.

For those FLUs which included more than one WUC, the MTBF was calculated in the following manner:

$$\text{MTBF} = \frac{(\text{SOT})(\text{QPA})}{\sum_{j=1}^{J} F_j}$$

where J = the number of WUCs included in the FLU

SOT = the six months operating time in hours

QPA = the number of identical FLUs in the system

F = the total number of failures.

It was assumed for this research study that operating hours and flying hours were synonomous.

K 13   OCALC-ACF   KC135A 4677A

MAINTENANCE ACTIONS, MANHOURS, AND ABORTS BY WORK UNIT CODE
PERIOD ENDING 76 JAN 31   FORMERLY 6-LOG-K261

PAGE 535
PCN D056B5006
RCS LOG-MMO(AR)7170

WUC NOUN	MONTH	INV	OP TIME	ABO	OCCURRENCES FAIL	OCCURRENCES OTH/MAL	OCCURRENCES TOT	MTB FAIL	MTB MAINT	MANHOURS SCHED	MANHOURS UNSCH	MANHOURS SHOP	SHOP ACTION UNITS REPR	SHOP ACTION UNITS CONDM	SHOP ACTION UNITS NRTS
4677A BOOM NOZZLE IN BALL	JAN	675	18064			3	5	12728	3394	4	5				
CAT GPA ACT LMT	DEC	585	15493		1	2	3	13244	3784	6					
C 1 1238	NOV	637	17355		3	4	7	14019	3505	5	7				
	OCT	665	20129			3	4	55119	3675	4	5				
	SEP	675	18590		1	3	5	7697	2449	7					
	AUG	652	16400			3	6	8926	2060	5					
	TOTALS		106031		5	18	30	21206	3534	31	17				
4677B BALL UNIVERSAL NOZ	JAN	675	18064			2	11	16971	1305	11	3	14	1		10
CAT GPA ACT LMT	DEC	585	15493		2	1	13	17659	1261	14	1	7			7
C 1 NO LMT	NOV	637	17355		1	3	15	56074	1368	16	5	12			12
	OCT	665	20129			3	14		1413	9		9	1		9
	SEP	675	18590				12		1738	14	1	16	2	1	13
	AUG	652	16400			6	13	53553	1339	11	9	11			11
	TOTALS		106031		3	15	78	35344	1359	75	19	69	4	1	62
4677C PULLEY	JAN*	675	18064		4		4	7273	5091	6	12				
CAT GPA ACT LMT	DEC	585	15493		2		3	7568	4816	9					
C 2 7349	NOV	637	17355		8	2	13	9346	5903	18	9				
	OCT	665	20129		4	2	6	22048	15748		4				
	SEP	675	18590					107764	53882						
	AUG	652	16400		1		1	21421	10711	8					
	TOTALS		106031		19	4	27	11161	7854	41	25				
46771 NOZZLE ASSY	JAN*	675	18064		70	57	413	217	42	332	411	376	54		10
CAT GPA ACT LMT	DEC*	585	15493		68	55	332	213	43	372	314	286	40		5
C 1 273	NOV*	637	17355		97	96	479	229	48	528	483	332	37		6
	OCT*	665	20129		84	92	411	246	55	377	523	313	37		1
	SEP	675	18590		64	47	277	281	61	323	253	350	40		2
	AUG	652	16400	1	76	69	319	276	57	493	272	284	33		2
	TOTALS		106031	1	459	416	2231	231	48	2425	2256	1941	241		26
46772 TAILCONE BOOM	JAN	675	18064		2	1	9	4628	1414	5	18	11	1		3
CAT GPA ACT LMT	DEC	585	15493		4	6	10	3784	1104	24	13	28	3		1
C 1 3367	NOV	637	17355		5	9	17	4005	950	18	38	31	3		4
	OCT	665	20129		5	3	21	6124	934	35	70	15	1		1
	SEP	675	18590		4	6	21	5987	1036	20	41	1			1
	AUG	652	16400			12	17	7650	974	27	39	4	1		2
	TOTALS		$\boxed{106031}$		20	39	95	5302	1116	129	219	90	9		12

Figure 8. Sample D056B5006 Report

In effect, the additional WUCs included in the FLU had the result of lowering the MTBF of the FLU because it was assumed that a failure of a component in the assembly results in a failure of the assembly itself.

For the tailcone assembly (WUCs 46772, 46783, and 46798),

$$\text{MTBF} = \frac{(106{,}031)(1)}{(20 + 48 + 55)} = 862 \text{ hours/failure.}$$

The numbers used in the calculation, for WUC 46772, are highlighted in Figure 8 on page 100.

SP. The number of already stock numbered parts that will be managed for the first time at bases where the system is deployed (SP) was set equal to zero for the KC-135 boom. It was assumed that the bases where the KC-135 boom system is deployed would not change during the period of this analysis. Since the value for SP did not vary between FLUs, it was not listed in Tables V and VI.

PA. The number of new "P" coded assemblies and components within each FLU was assumed to be zero for all FLUs in the KC-135 boom system.[1] Since this variable did not vary between FLUs it was not listed in Tables V and VI with the other variables.

---

[1]According to T.O. 00-25-195, "Source, Maintenance and Recoverability Coding of Air Force Weapons, Systems, and Equipment," the term "P coded" applies to those parts that are procured, as opposed to being manufactured at the depot or base (76:2-1).

QPA. QPA is the number of identical FLUs within the parent system. The appropriate value for most FLUs was obtained from T.O. 1C-135(K)A-4 (81). There was one exception to this. The ruddevator quadrant assembly was assigned a QPA of four because of the aggregation of the four separate but identifiable parts.

RIP. The values for the fraction of FLU failures that are expected to be repaired in-place on the aircraft (RIP) were obtained from the D056B5505 report. Part I of this report, "On-Equipment Actions," was a record of all malfunctions that were reported during the period. A sample of Part I of the D056B5505 report is shown in Figure 9 on page 103. The definitions of the on-equipment "Action Taken Codes," at the tops of the columns, are listed in T.O. 1C-135(K)A-06 (77:IV-01). Basically, the only two columns that were not considered as in-place repair actions were the "P", removed to be later reinstalled, and "R", removed and replaced, columns.

RIP was calculated in the following manner:

$$RIP = \frac{\sum_{j=1}^{J} (TO_j - PR_j)}{\sum_{j=1}^{J} TO_j}$$

where J = the number of WUCs included in the FLU

TO = the total number of occurrences (failures) for each WUC

PR = the number of P and R coded occurrences (failures) for each WUC.

OCALC-ACF SUMMARIZED MAINTENANCE ACTIONS FOR SELECTED WORK UNIT CODES PCN D056B5505 PAGE 273
KC135A 46772 MC6037 PERIOD ENDING 76 MAR 31 FORMERLY 5-LOG-K261 RCS LOG-MMO<AR>7169
WUC 46772 TAILCONE BOOM CAT IND C

PART I - ON EQUIPMENT ACTIONS

--HOW MALFUNCTION-- CODE	NOUN	CURR MO OCCURRENCES FAIL	TWELVE MONTH ----OCCURRENCES---- FAIL	OTHMAL	TOTAL	------TWELVE MONTH OCCURRENCES BY ACTION TAKEN------ F REPR	PR REM	G ATCH	KL ADJ	Z CRSN	V CLN	X TEST	S R&R	EHJ OTHER	TWELVE MONTH UNITS	TWELVE MONTH M/HRS
TYPE 1																
020	WORN			4	4			4							4	13.2
080	DEFECTIVE LAMP		1		1		1								1	1.5
117	DETERIORATED		1	1	2		1	1							2	4.8
127	ADJUST IMPROP		1	1	2			1	1						2	4.5
170	CORR-MILD/MOD		5		5					5					5	6.5
190	CRACKED	1	4	7	11		4	7							11	36.3
242	FAIL TO OPER		2		2		2								3	15.5
381	LEAKING		3	2	5		3	2							5	23.3
601	DETONATION			1	1			1							1	.6
660	STRIPPED			1	1			1							1	1.0
730	LOOSE	2	4	1	6			1	4			1			6	7.1
750	MISSING			1	1			1							1	3.0
780	BENT		25	5	30		24	5	1						31	235.4
865	COATING DEFECT			1	1			1							1	4.0
947	TORN			1	1			1							1	1.0
	TOTAL	3	46	26	73		35	26	6	5		1			75	357.7
TYPE 2																
105	BOLTS LOOSE			31	31	1	1	29							31	42.0
106	BOLTS MISSING			13	13			13							13	6.1
108	BRKN SAFTY WR			2	2			2							2	.8
230	DIRTY			12	26		7	5			14				26	64.1
246	IMPROP MAINT			1	1		1								1	6.0
301	FORIN OB DAM			2	3		1	1			1				3	7.5
	TOTAL			61	76	1	10	50			15				76	126.5
TYPE 6																
799	NO DEFECT				40							23		17	40	56.5
800	NO D FAC MAIN				27		18					1	8		27	92.0
805	NO DEF NOC				1			1							1	.3
	TOTAL				68		18	1				24	8	17	68	148.3
	WUC TOTAL	3	46	87	217	1	63	77	6	5	15	25	8	17	219	633.0

12 MONTHS UNITS & MANHOURS FOR OTHER ACTIONS A/T UNITS Q 27 HOURS 100.5 A/T UNITS T 7 HOURS 65.3 A/T UNITS L 6 HOURS 37.6 A/T UNITS Y 3 HOURS 17.2 A/T UNITS INVL HOURS .0

Figure 9. Sample D056B5505 Report--Part I

For the tailcone assembly (WUCs 46772, 46783, and 46798),

$$RIP = \frac{(217-63) + (472-29) + (486-11)}{217 + 472 + 486} = .83 \left\{ \begin{array}{l} \text{fraction} \\ \text{repaired} \\ \text{in-place} \end{array} \right.$$

UC. Unit costs (UC) were obtained from COSPERANK for reparable items and from item managers for expendable items. The only figures available for unit cost, however, were for the prices paid when the items were last purchased. In light of the rates of inflation experienced in recent years, it was felt that all prices should be adjusted. Factors used for these adjustments were taken from "Cost Escalation Study 110C" published by the Office of the Comptroller, Aeronautical Systems Division, Wright-Patterson AFB, Ohio (9). All prices were adjusted to reflect estimated fiscal year (FY) 1976 dollars. In order to update these costs, it was necessary to contact all of the respective item managers to find out the date of the last buy of each stock numbered item. No attempt was made to adjust for the size of the procurement buy, a factor which definitely affects the unit price.

FY 1976 unit costs were calculated in the following manner:

$$UC_{76} = \frac{UC_{FY}}{CI}(FI)$$

where UC_{FY} = the unit cost in the FY of the last buy

CI = the appropriate correction index

FI = the forecasted index for FY 1976.

For the ruddevator boost unit,

$$UC_{76} = \frac{\$2838.00(\text{FY } 1974)}{.914} \times 1.082 = \$3359.65$$

The tailcone assembly was not used for this sample calculation because it was last purchased in FY 1976. The correction index inflated the original unit cost of the ruddevator boost unit to an FY 1975 unit cost which in turn was converted to an FY 1976 unit cost using the factor 1.082.

The only FLU that required an individualized unit cost calculation was the ruddevator quadrant assembly. The problem of assigning a unit cost to this collection of parts was felt to be treated best by using a weighted average of the costs for the four stock numbered parts in the FLU. The cost was weighted on the basis of the number of supply demands for the four parts, and the number of demands for each part was obtained from the respective item manager. Since the parts were purchased at different times, the original costs were inflated to FY 1975 costs first, and then the average unit cost was calculated.

UF. The utilization or use factor (UF) is the ratio of the number of operating hours to the number of flying hours for each FLU. For this analysis it was assigned a value of one which means that flying hours are equivalent to operating hours.

W. The unit weight of the FLU was taken from the K051.PN8L report for the major stock numbered item in the

assembly. For items not listed, or for which the weights were not listed in the report, weights were obtained from the shipping office of the depot where the item is managed. A sample K051.PN8L report is shown in Figure 10 on page 107 and the unit weight of the tailcone is highlighted.

The weight of the ruddevator quadrant was a weighted average of the four parts considered in this FLU, weighted by the frequency of demands for the parts.

This completes the discussion of the KC-135 boom system and the methodology for determining values for each of the variables. The complete list of all variables is shown in Appendix B. Using these values resulted in a KC-135 boom system logistics support cost figure of merit of $13.33 million. The complete computer output listing is shown in Appendix E.

The next chapter describes the AARB, its analysis, and a comparison between the two boom systems.

WEAPON SYSTEM [illegible] 135A [illegible] LOGISTIC SUPPORT COST FILE MAINTENANCE REGISTER K051.PN8L PAGE 275
CHANGED DATA ELEMENTS ARE DENOTED BY C (COMPUTER) OR M (MANUAL) DATE PROCESSED 76 FEB 01

WUC	CAT IND	ACC	NSN	PRIME ALC	NOUN	ERRC	UNIT PRICE	WEIGHT OR SPEC	INV	QPA	SRA OR USE	FCTR	% DEP COND	SPCL CODES GFAE	EXMPT	OLD WUC
[illegible]		A	9999999999999999		RUD LK QD ROLLE	-	$0.00			2		1.00				
[illegible]		6	1560000686535FL	D	FORK ASSEMBLY,P	T	$1,019.00		8		C	$18	00			
		5 C	1560006526168FL	CD C	GUARD ASSEMBLY,	C N C	$22.54	C	0		C	$0	00			
		5 C	5120002139678FL	CD	---------------	C U C	$152.20	C	1			-----	00			
		A	9999999999999999		BOOM FORK ASSY	-	$0.00			1		1.00				
[illegible]		5	1560000682535FL	D	FORK ASSEMBLY,P	T	$1,019.00		8		C	$18	00			
		A	9999999999999999		FITTING FWD PIV	-	$0.00			1		1.00				
[illegible]	C	Y	9999999999999999		BOOM FORK SHAFT	-	$0.00			1		1.00				
[illegible]	C	Y	9999999999999999		BOOM FORK THRUS	-	$0.00			1		1.00				
[illegible]	C	Y	9999999999999999		BOOM FORK SHAFT	-	$0.00			1		1.00				
46766			1680006760158FL		*** DELETED NO FIELD DATA HISTORY ***											
	CC	Y	9999999999999999		TUBE WELD TELES	-	$0.00			1		1.00				
[illegible]		6	1560005472088FL	D	GLAND,BOOM SEAL	N	$92.16		0			$0	00			
			1680006760158FL		*** DELETED NO FIELD DATA HISTORY ***											
	C	A	9999999999999999		SLIDING GLAND S	-	$0.00			1		1.00				
46771		6	1560003044697FL	D	BALL, UNIVERSAL	T	$266.50		9			$130	00			
		6	1560003970196FL	D	---------------	N C	$326.44		0			$0	00			
		6	1560006049353FL	D	HEAD ASSEMBLY,N	T	$8,083.00		9			-----	00			
		6	1560006566170FL	D	NOZZLE ASSEMBLY	T	$2,615.00		30			$404	00			
		6	1560006703691FL	D	---------------	P	$59.39		1			-----	00			
		6	1560006760158FL	•	---------------	-	--------		0			-----	00			
		6	1560006793439FH	D	NOZZLE ASSEMBLY	T	$1,348.00		44			-----	00			
		6 C	1560006864523FL	CD C	TUBE, NOZZLE ER	C N C	$34.32	C	0		C	$0	00			
		6	16800[illegible]	F	AMPLIFIER,ELECT	T	$125.00	C	8			-----	00			
		6 C	1680007568152	CF C	PUMP,FUEL TRANS	C T C	$1,650.00	C	69		C	$292	00			
	C	A	9999999999999999		NOZZLE ASSY	-	$0.00			1		1.00				
46772		6	1560006317599FL	D	CONE ASSEMBLY,B	T	$12,172.00		50			$303 C	17			
			1560008566054FL		*** DELETED NO FIELD DATA HISTORY ***											
	C	A	9999999999999999		TAILCONE BOOM	-	$0.00			1		1.00				
46775			1680006760158FL		*** DELETED NO FIELD DATA HISTORY ***											
	CC	Y	9999999999999999		SURGE BOOT	-	$0.00			2		1.00				
46776		Y	9999999999999999		SURGE BOOT INF	-	$0.00			1		1.00				

Figure 10. Sample K051.PN8L Report

IV. Analysis of the Advanced Aerial Refueling Boom System

This chapter describes Douglas Aircraft Company's proposed Advanced Aerial Refueling Boom (AARB) system. It describes the AARB system in some detail in order to convey the rationale behind the selection of the AARB FLUs, and to highlight the differences between the AARB and the KC-135 boom. These differences, and the resulting values for the logistics support cost parameters of the FLUs, are what ultimately determines the difference in the logistics support cost figures of merit. This chapter compares the logistics support cost contributions of the FLUs both within each weapon system and between the two boom systems. It also compares the final figures of merit for the two booms.

Description of the AARB

The basic design of the AARB is very similiar to the KC-135 boom design, a design that has been used successfully for over 15 years. The boom is attached to the underside of the fuselage aft of the wings. A pivot system allows the boom to move both vertically and horizontally. Telescoping tubes allow the boom to extend and retract, and carry fuel to the nozzle at the aft end of the boom. Movable flight control surfaces allow the boom operator to maneuver the boom within a prescribed envelope.

Although the basic design of the AARB is similar to the KC-135 boom, design improvements--some of them radical

departures from past boom designs--have been incorporated. If successful, these design features will allow the AARB to overcome some of the limitations of the KC-135 boom. A detailed description of the KC-135 boom was presented in Chapter III. The following discussion of the AARB describes the differences and the similarities between the two systems, and identifies the potential impact of the differences in terms of system and FLU parameters and logistics support costs. The AARB components that were selected as FLUs for the logistics support cost analysis are identified also.

The selection of an AARB component or assembly as a FLU, for the logistics support analysis, was based on the following criteria: (1) an AARB component or assembly was similar in function yet different in design to a corresponding component or assembly which was a large logistics support cost contributor in the KC-135 boom system, or (2) an AARB component or assembly had no corresponding part in the KC-135 boom system yet it seemed likely to add significantly to the logistics support cost of the AARB.

As described in Chapter II, initial selection of the KC-135 boom system FLUs was based mainly on the logistics support cost rankings given in the K051.PN3L report. Since the chosen KC-135 boom system FLUs were significant logistics support cost contributors, it was felt that the corresponding functional components on the AARB would also contribute significantly to the logistics support cost of the AARB.

Parallel FLUs were then chosen so that a direct comparison of design parameters and logistics support costs could be made.

A basic assumption in the development of the AARB was that it would provide significant improvements over the existing KC-135 boom system.

Advantages of the AARB. The major advantages of the AARB are related to design changes. Necessarily, the logistics support cost aspects of the AARB are also related to these changes. The advantages of the AARB include:

1. Increased length.
2. Larger refueling envelope.
3. Improved controllability.
4. Greater fuel flow rate.
5. Independent disconnect capability.

The AARB is ten feet longer than the KC-135 boom, and this extra length provides an additional five feet of vertical separation between the tanker and the receiver. This additional separation is especially important when refueling large aircraft like the C-5A.

The AARB has a larger refueling envelope than the KC-135 boom. The increased length, together with the new rolling pivot system and the fly-by-wire control system, will substantially increase both the size of the refueling envelope and the maneuverability of the AARB. The existing KC-135 boom does not meet the refueling envelope limits required by MIL-F-38363B(USAF)(2:4). Figure 11 on page 111 shows a comparison of the three refueling envelopes.

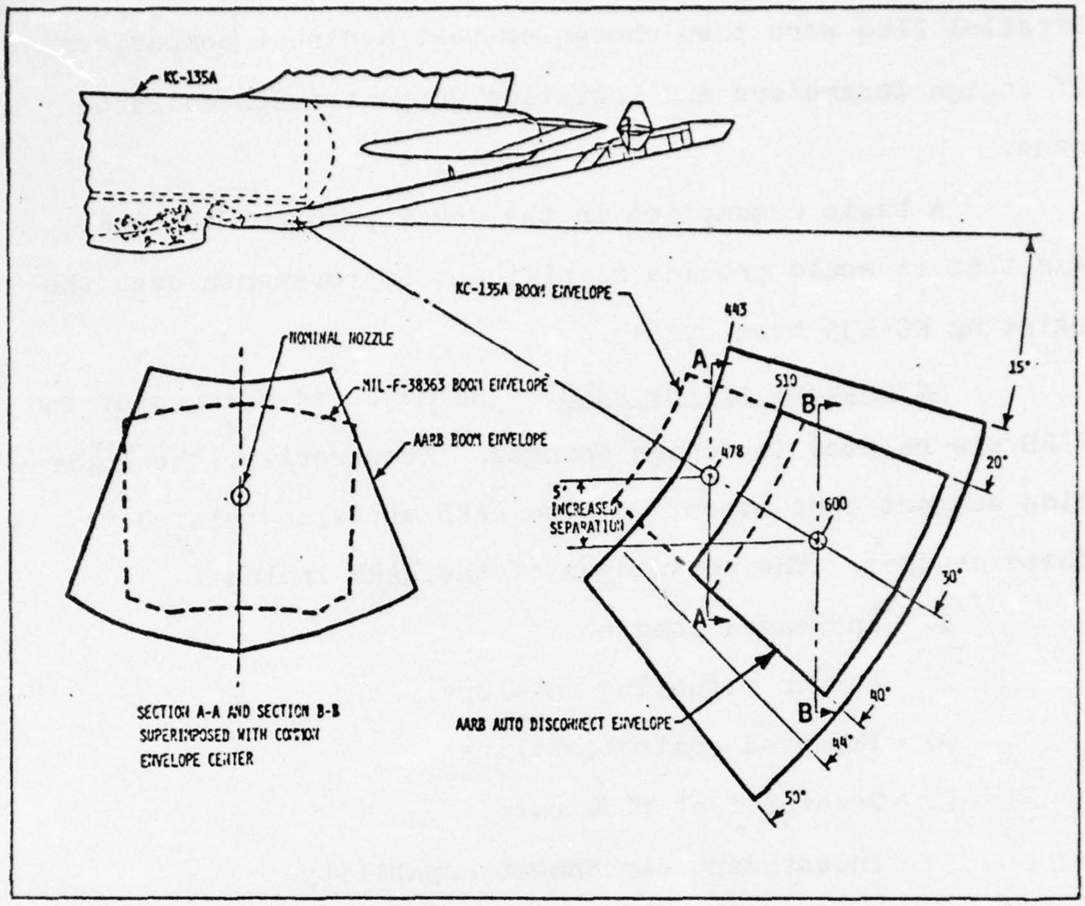

Figure 11. Refueling Envelope Comparison [AARB Summary Report (2:3)]

Rolling Boom Pivot System. The substantial increase in the size of the refueling envelope of the AARB is due mainly to the new rolling boom pivot system. The main difference between the rolling pivot system of the AARB and the boom fork assembly of the KC-135 is in the method of movement. The KC-135 boom fork shaft has a vertical orientation. To move vertically, the boom pivots at its points of attachment in the boom fork. For lateral boom movement, the boom fork rotates on its vertical shaft.

In contrast to the KC-135 boom, the boom fork of the AARB has a horizontal orientation. Now, lateral movement of the boom will be accomplished by a rolling movement of the fork. Figure 12 on page 113 shows the KC-135 yawing boom pivot and the AARB rolling boom pivot in a schematic drawing.

With the KC-135 boom system, when the boom operator yawed the boom, more of the side area of the boom entered the slipstream. This created high lateral restoring forces which, in turn, required larger control surfaces and forces in order to maneuver the boom. With the AARB system, the rolling motion of the boom will result in less side loading on the boom because the longitudinal axis of the boom will be more nearly aligned with the slipstream. Therefore, smaller control surfaces and forces can be used to give better maneuverability.

It is expected that the logistics support cost aspects of the new rolling boom pivot assembly of the AARB will not be much different than those of the KC-135 boom fork assembly. The new rolling pivot assembly should show some improvement in the mean time between failures (MTBF) because the old KC-135 boom forks are beginning to show their age with an occasional crack. A fleet-wide inspection program has been under way to identify cracked fork assemblies; however, very few have been found. An increased MTBF for the rolling pivot assembly should mean a reduction in logistics support costs because of fewer failures. On the other hand,

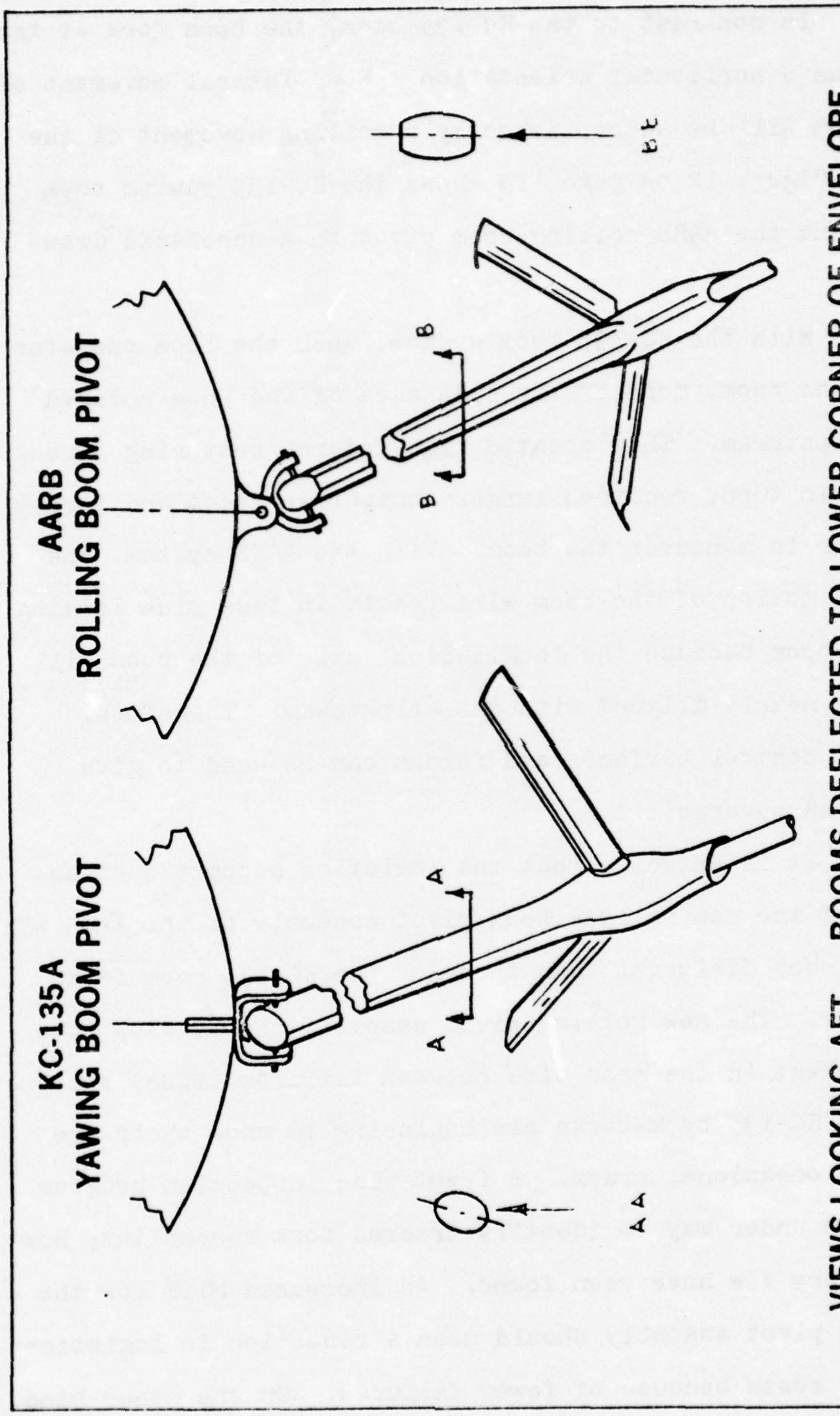

Figure 12. Pivot Axis Arrangements: Yawing and Rolling Booms [AARB, Volume I, Technical Summary (3:2)]

the improved reliability of the AARB pivot system may be partially offset by the higher unit cost and the addition of a hydraulic actuator tilt mechanism that is used when stowing the boom against the fuselage.

The rolling boom pivot assembly, although not yet completely defined, was selected as one of the AARB First Line Units (FLUs) because it replaced the KC-135 boom fork assembly.

Flight Control Surfaces. With the new rolling pivot system, smaller flight control surfaces and forces are required to maneuver the AARB. Partially for this reason, the AARB flight control surfaces have been redesigned. Whereas the KC-135 ruddevators have a "V" Tail configuration, the AARB has an all-movable horizontal elevator with two tip mounted fin and rudder combinations--a "U" Tail configuration. The elevator controls the vertical movement, and the rudders control roll movement. Figure 13 shows the "U" and "V" Tail configurations.

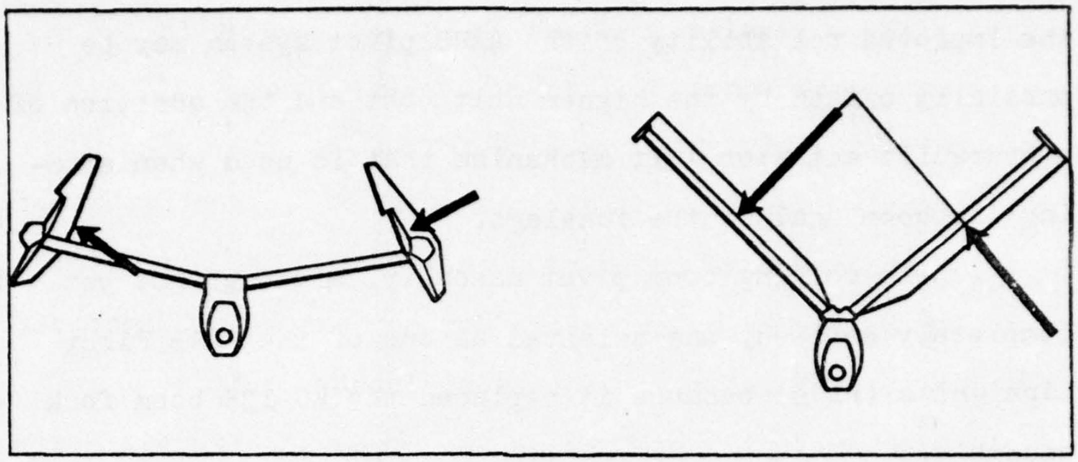

Figure 13. "U" and "V" Tail Configurations
[AARB Summary Report (2:6)]

With the "U" Tail configuration, the control surfaces are more nearly aligned with the pitch and roll forces required to maneuver the AARB in the refueling envelope. Also, as Figure 13 shows, with this new configuration the lateral forces are much closer to the center of the boom thereby lessening the bending and twisting forces on the boom assembly. Consequently, smaller and more efficient control surfaces can be used. The smaller control surfaces reduce weight and the smaller bending and twisting forces permit other weight savings throughout the boom structure, including the yoke attachment and bearings. These weight savings partially offset the added weight due to the increased length of the AARB.

It is expected that the logistics support cost aspects of the flight control surfaces of the AARB will be similar to the ruddevators of the KC-135. All are of aluminum honeycomb construction, just as the ruddevators are.

Therefore, all were assumed to have similar logistics support cost parameters. The only difference is that there are five surfaces on the AARB -- the elevator, two fins, and two rudders. This should mean a corresponding logistics support cost increase.

The five flight control surfaces were selected as one of the AARB FLUs because they replaced the two KC-135 ruddevators.

<u>Fly-By-Wire System</u>. A radical change from the KC-135 boom system is in the fly-by-wire flight control system (FBWS) of the AARB. In the KC-135 boom system control cables partially moved the ruddevators. In the AARB system electrical wires replace the cables.

According to the Contract Proposal submitted by Douglas Aircraft Company, the FBWS is based on an existing Sperry 1819B Digital Airborne Computer which will sense and process (1) boom operator command inputs, (2) boom position, (3) control surface position, (4) internal boom forces, and (5) acceleration rates. In addition to the normal, manual boom positioning and telescoping control mode, the FBWS incorporates an Automatic Load Alleviation System (ALAS). In the ALAS mode, when the tanker is coupled with the receiver aircraft, this system will continuously trim the boom flight control surfaces to prevent the buildup of unbalanced aerodynamic and mechanical loads (7:20-21).

Major components of the FBWS include the following:

1. A Sperry 1819B Digital Airborne Computer.

2. A Data Adapter Unit which provides the interface between the computer and the control system components.

3. The Fly-By-Wire Unit which provides dual channel electronics for the control system servo-actuators.

4. The hydraulics servo-valves and servo-actuators which operate the boom telescoping mechanism and the flight control surfaces respectively.

5. The control system sensors which sense boom and flight control surface positions and accelerations.

6. The Controller Interface Unit which provides the interface to operate KC-135 elements like the pilot receiver director lights and the boom operator's instruments.

7. The ALAS Stick Trim Servos which trim the boom operator's control stick during ALAS coupled flight.

It is expected that the FBWS will be one of the major logistics support cost contributors of the AARB for several reasons. There will be many complex new components and the unit cost will be high for the components. Additional training will be required for support personnel and new support equipment will be required at all supporting bases and at the depot. The FBWS (with a conservative unit cost of $25,000) is the single most expensive assembly in the AARB. This cost only includes the computer, the data adapter unit, and the fly-by-wire unit. Other elements, like the servo-actuators and the sensors, have been considered separately.

There is nothing in the KC-135 boom system that can be compared with the FBWS. It adds a whole new, unproven performance dimension. For this reason, the FBWS consisting of the computer, the data adapter unit, and the fly-by-wire unit was selected as one of the AARB FLUs.

Hydraulic Servo-Actuators. Like the KC-135 ruddevators, the AARB flight control surfaces are powered by hydraulic actuators. However, unlike the KC-135 ruddevator boost units which "boosted" the mechanical inputs that were carried from the boom operator's controls to the ruddevator quadrant sections, the servo-actuators in the AARB flight control system will position the surfaces in response to electrical signals sent through the FBWS. To provide a redundant capability, each of the AARB flight controls will be powered by two servo-actuators. This redundant capability will minimize the possibility of a "hard-over" condition in which a surface would rapidly travel to an extreme position. The servo-actuators will also provide a snubbing action that will replace the ruddevator lock system on the KC-135 boom.

It is expected that the logistics support costs for the AARB servo-actuators will be higher than the corresponding logistics support costs of the KC-135 ruddevator boost units for two reasons. First, there will be six servo-actuators, two for the elevator and a pair for each of the rudders, instead of just two boost units as in the KC-135 boom. Second, these modern electrical servo-actuators are more expensive than the mechanical actuators. It is possible that the MTBF

of the servo-actuators could increase due to planned technological advances which include improved seals. In this case, the logistics support costs would decrease. On the other hand, the increased complexity of the servo-actuators might decrease the MTBF and the logistics support costs would increase.

The servo-actuators were selected as one of the AARB FLUs because they replaced the two KC-135 ruddevator boost units.

Sensor Package. There are 16 sensors on the AARB which include Linear Voltage Differential Transformers (LDVT), Rotary Voltage Differential Transformers (RVDT), and Linear Accelerometers. These units sense boom and control surface position, internal forces, and accelerations and provide signals to the FBWS computer for processing. They also preclude the need for the three position transmitters which work in conjunction with the KC-135 boom azimuth, elevation and telescope control units to provide signals for the boom operator's panel display instruments. For this logistics support cost analysis, these sensors were considered to be comparable to the KC-135 boom position transmitters.

It is expected that these sensors will be a major contributor to the logistics support cost of the AARB for three reasons: (1) there are 16 sensors in the AARB rather than 3 as in the KC-135 boom, (2) the unit cost of a sensor is approximately three times the unit cost of a transmitter, and (3) the MTBF is not expected to change significantly.

The sensors were selected as one of the AARB FLUs because of their functional similarity to the KC-135 boom position transmitters.

Nozzle Assembly. According to Douglas Aircraft Company's proposal, the nozzle for the AARB was designed around two main objectives: (1) an increased fuel flow rate during fuel transfer, and (2) incorporation of a disconnect capability that is independent of the proper operation of the electrical and hydraulic system of the receiver aircraft (7: 16-17).

In many respects, the Advanced Aerial Refueling Nozzle (AARN) is very similar to the KC-135 boom nozzle. The forward end of the nozzle housing attaches to the recoil shock absorber, and the aft end of the nozzle housing forms part of the universal ball joint. The forward end of the nozzle head mates with the housing to complete the universal ball joint, and the aft end of the nozzle head fits into the aerial refueling receptacle of the receiver aircraft. The function of the universal ball joint is to compensate for slight misalignments between the AARB and the receiver.

In order to meet the requirement for an increased fuel transfer rate, yet still fit the receptacles in the receiver aircraft, it was necessary to change the dimensions of the nozzle head. The primary change was to decrease the thickness of the walls of the nozzle head. This necessitated changing the nozzle material from an aluminum alloy

to a high-strength alloy steel, and will require more advanced metal working technologies for manufacturing.

In order to meet the second requirement for an independent disconnect capability, it was necessary to add an auxiliary system in the nozzle. This independent disconnect system contains a high pressure air reservior and pneumatic lines, actuators, mechanical linkages, and movable toggle striker plates. Upon a signal from the boom operator, the toggle striker plates will rotate away from the toggles of the receiver aircraft thereby allowing the boom to be extracted. Unfortunately, parts of this complicated disconnect system must also fit into the nozzle head walls.

In the past, electrical discontinuities or mechanical malfunctions between the tanker and the receiver have prevented normal boom disconnects. Such malfunctions may result in the necessity for a "brute force" disconnect. Such disconnects can cause damage to either the tanker or the receiver or both.

It is expected that the AARN will be a major logistics support cost contributor. There are several reasons for this expected increase. First, the unit cost of the AARN will be significantly higher than the KC-135 boom nozzle because of the new material, the thinner walls, the advanced manufacturing technologies, and the added complexities of the independent disconnect system. Second, the MTBF is not expected to change.

For this AARB logistics support cost analysis, the independent disconnect system was assumed to be an integral part of the AARN. The AARN was selected as one of the AARB FLUs because of its similarity to the KC-135 boom nozzle.

Signal Coil Amplifier System. The signal coil is another component that is imbedded in the nozzle head. Like the KC-135 signal coil, the signal coil in the AARN is part of the signal coil amplifier system. The coil, itself, is an induction coil that completes an electrical circuit which includes the electrical system of the receiver aircraft. Correct positioning of the coil--and the nozzle--in the refueling receptacle of the receiver, activates the latching toggles and provides interphone communication between the tanker and the receiver. The signal coil system must function properly or the normal, automatic disconnect capability is lost.

Therefore, several design changes have been made in an attempt to improve the electrical continuity of the signal coil amplifier system. First, the signal coil wire terminals were moved to a position forward of the universal ball joint, and the wires were routed through the nozzle. This should prevent the refueling receptacles of some receiver aircraft--mainly the C-5A--from cutting the wires. Second, a single continuous cord replaces the track and sliding brush conductor system in the KC-135 boom. This retractile (retractable, coiled) cord is encased in a steel tube for the complete length of the AARB. This change should eliminate most of the

signal coil circuit discontinuities, electrical arcing, noise and other maintenance problems caused by friction wear and debonding. The retractile cord will also carry the signals for the independent disconnect system.

It is expected that the logistics support cost contribution of the signal coil amplifier system of the AARB will be smaller than that of the KC-135 boom. Although the identical signal coil amplifier and signal coil that are used in the KC-135 boom, will be used in the AARB, the primary factor in the logistics support cost decrease should be an increase in the MTBF of the system. It is estimated that the retractile cord will increase the MTBF by approximately three times.

The signal coil amplifier system was selcted as one of the AARB FLUs because of its similarity to the KC-135 signal coil amplifier system.

Tailcone Assembly. The configuration of the structural and telescoping tubes of the AARB is different from the KC-135 boom, although similar in concept. The outer structural and inner fuel tubes are fixed, as in the KC-135 boom. At the aft end of the fixed structural tube is the tailcone assembly. The AARB tailcone is similar in function to the KC-135 boom tailcone. However, there are two major differences between the two tailcones. The new AARB tailcone will be made of fiberglass, and its present design does not include provisions for a fuel dump actuator assembly.

The AARB, as designed by Douglas Aircraft Company, was designed to be used on the Douglas DC-10 aircraft--one of the aircraft being considered for the ATCA. As such, it was designed without a fuel dump actuator because the DC-10 has wing tip fuel dump masts. However, the KC-135 dumps fuel through its boom system. In the event that fuel has to be dumped from the KC-135, the fuel dump actuator depresses the check valve in the end of the nozzle. Since the AARB is going to be installed on a KC-135 for the feasibility demonstration tests, and possibly later as a modification to part of the KC-135 fleet, a fuel dump actuator assembly and the associated hydraulic lines and valves will have to be installed in the AARB tailcone. For this reason, a fuel dump actuator assembly identical to the assembly used in the KC-135 boom was assumed to be installed in the AARB tailcone.

It is expected that the logistics support cost contribution of the AARB tailcone will be lower than that of the KC-135 boom. In the past, most tailcone problems were caused by inadvertant contact with the receiver aircraft. It is anticipated that the frequency of damage to the tailcone will decrease due to the increased controllability and the larger refueling envelope of the AARB. Therefore, it is expected that control system improvements will indirectly increase the MTBF of the tailcone. Another factor in the reduced logistics support cost should be the change from an aluminum to a fiberglass tailcone. It is expected that fewer hours will be spent in on-equipment maintenance because it is

easier to repair minor holes and cracks in fiberglass than in aluminum. However, an offsetting factor should be the increased unit cost of the AARB tailcone.

The tailcone was selected as one of the AARB FLUs because of its similarity to the KC-135 tailcone.

<u>Sliding Gland Seal</u>. At the forward end of the telescoping inner structural extrusion is a sliding gland seal. It is similar in function to the KC-135 gland seal in that it prevents fuel from leaking past the aft end of the extrusion and into the boom; however, it is not as complex. Rather than being many alternate layers of felt wipers, teflon O-rings, scrapers and spacers encased in a metal housing; the AARB sliding gland seal will contain only one thin carbon-filled teflon bearing strip and a single "Poly Pak" type of seal, made from a material specially formulated for improved dynamic sealing properties and long life (4:9).

It is expected that the logistics support cost contribution of the AARB sliding gland seal will be lower than that of the KC-135 sliding gland seal. The primary reason is that its MTBF is expected to be greater. In fact, the manufacturer of the seal expects it to last the life of the AARB. An offsetting factor may be an increase in unit cost.

Because of its functional similarity to the KC-135 sliding gland seal, the sliding gland seal was selected as one of the AARB FLUs.

<u>Surge Boot</u>. Like the KC-135 boom system, the AARB also has a surge boot. However, the AARB only has one

rubberized boot. Its function is similar, in that it absorbs fuel surges when the nozzle check valve closes, but its construction and location are different. The surge boot, filled with pressurized air, fits in a cavity formed by the telescoping inner structutal extrusion on the bottom and an "H" shaped extrusion on the top. When the nozzle check valve closes, after an inadvertant disconnect, the pressurized fuel is forced up through holes in the top of the lower extrusion and it compresses the surge boot. In the KC- 135 boom, the surge boots were forced outward against a restraining tube. Figure 14 on page 127 shows the arrangement of the extrusions and the surge boot.

It is expected that the logistics support cost contribution of the AARB surge boot will be lower than that of the KC-135 surge boots. Although the unit cost will be higher, there will be just one boot which extends the length of the boom rather than two smaller boots. It is expected that there will be fewer fuel leaks--and therefore a higher MTBF--because of the construction of its restraining cavity. Furthermore, it is expected to be easier to replace because it can be extracted and replaced through the aft closing bulkhead. The KC-135 boom must be largely disassembled in order to remove and replace the KC-135 surge boots.

The surge boot was selected as one of the AARB FLUs because of its similarity to the KC-135 surge boots.

Telescoping Drive Assembly. The AARB has a telescoping drive assembly that is similar to the KC-135 assembly.

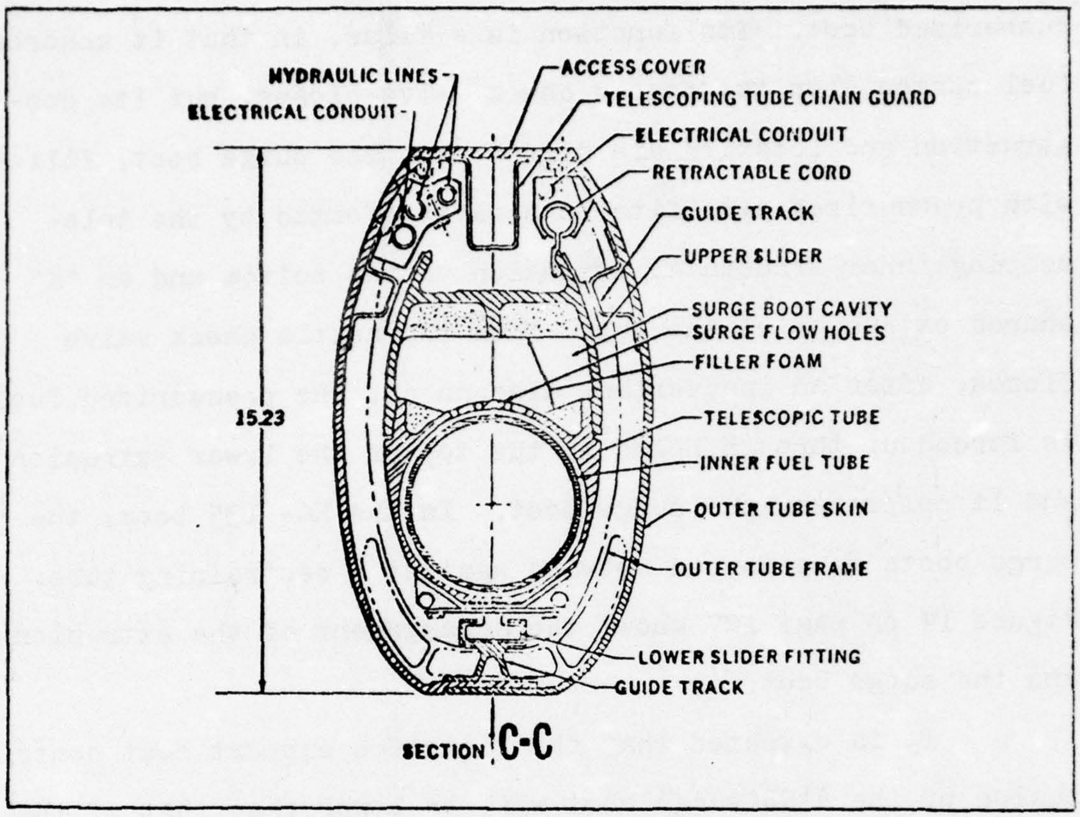

Figure 14. AARB Cross Section
[AARB Summary Report (2:13)]

except that it will have a larger capacity in order to handle the increased loads of the larger AARB. The gearbox will be a modified KC-135 extension drive gearbox and the chain and cables will be larger. The motor will be an "off-the-shelf" motor incorporating a servo control value (7:175). The servo valve will replace the telescope control unit on the KC-135 boom.

It is expected that the logistics support cost contribution of the telescoping drive assembly of the AARB will be lower than that of the KC-135 telescoping drive assembly. The primary factor should be an increase in MTBF because of

various design improvements. On the AARB, the complete drive system will be on top of the boom assembly rather than on the side and bottom. Besides providing easier access, all of the chain can be lubricated. In the KC-135 telescoping drive assembly, there was an 18-inch segment of the chain that could not be lubricated. As might be expected, occasional chain failures resulted due to the lack of lubrication.

The telescoping drive assembly was selected as one of the AARB FLUs because of its similarity to the KC-135 telescoping drive assembly.

Extension and Retraction Shock Absorbers. Finally, the extension and retraction shock absorbers were selected as an AARB FLU. These shock absorbers are located at either end of the AARB to protect the boom structure from the shock of full extension or retraction against the travel stops. These items replace the single ring spring assembly on the KC-135 boom. Very little information on the extension and retraction shock absorbers was available. However, because they were new components, they were included in the analysis in recognition of the fact that they could have a significant logistics support cost contribution. Further information, as it becomes available, will either confirm or invalidate the inclusion of these shock absorbers.

There were several other FLUs included in the KC-135 logistics support cost analysis that were not included in the AARB analysis. The KC-135 boom ruddevator quadrant was a complex assembly of parts designed to support and control the

ruddevators. Corresponding components do not exist in the AARB. The elevation and azimuth control units in the KC-135 boom have been replaced by numerous, diverse components in the FBWS of the AARB. Consequently, they are not included as separate FLUs in this AARB analysis.

Finally, there were several components in the KC-135 boom system that had significant logistics support cost contributions, however, the same identical part is being used in the AARB. Since the logistics support cost contributions would have been the same in both systems, they would have added nothing to the analysis. These components were the recoil shock absorber assembly and the stowage shock absorber assembly.

Table VII on page 130 shows a comparison of the 12 and 15 FLUs that were included in the AARB and KC-135 boom logistics support cost analyses respectively.

<u>The feasibility test phase</u>. The AARB has gone through several stages of development, evolving to the present configuration. The first version was a "V" Tail ruddevator design. A fly-by-wire capability, including automatic load alleviation was added later. An advanced nozzle was then designed to meet the requirement for higher fuel transfer rates. The new control surface design--a "U" Tail--was developed and feasibility studies were reported in January 1976. The test phase, scheduled to begin in September 1976, is intended to demonstrate the feasibility of the AARB design. It will include flight testing of the AARB, mounted on the KC-135, and

Table VII AARB and KC-135 Boom FLU Comparison			
WUC	DESCRIPTION	AARB	KC-135
4676B	Pivot System	X*	X
46766	Flight Control Surfaces	X	X
46755	Fly-By-Wire System	X	
46794	Hydraulic Actuators	X	X
51921	Position Sensors	X	X
46771	Nozzle Assembly	X	X
46851	Signal Coil Amplifier System	X	X
46772	Tailcone Assembly	X	X
4676H	Sliding Gland Seal	X	X
46773	Surge Boot(s)	X	X
46778	Telescoping Drive Assembly	X	X
46765	Extension & Retraction Shock Absorbers	X	
46768	Ruddevator Quadrant Assembly		X
4676A	Ruddevator Lock Roller Assembly		X
46857	Elevation Control Unit		X
4685A	Azimuth Control Unit		X
46854	Telescoping Control Unit		X
TOTAL FLUs		12	15
*X indicates that the FLU is included in the analysis.			

for the first time, transfer of fuel. Work to date has consisted of ground tests, including wind tunnel tests of specific components, and engineering analyses for all of the defined components.

The next section of this chapter describes the methodology and data sources used for estimating the weapon system, system and FLU parameters for the logistics support cost analysis of the AARB.

Values for AARB Variables

Some aspects of the AARB design were still relatively uncertain during this research project. Specifications were not available for all components of the AARB. Indeed, some components were not yet fully defined. Some aspects of the design were more completely specified, however even these were largely unproven. For these reasons, much of the cost, reliability, and repair data for the AARB FLUs are uncertain at best. The logistics support cost estimate for the AARB likewise should be considered for what it is--an initial figure of merit, based on preliminary design information. Future estimates should become more refined as the components become better defined.

Determination of values for weapon system variables. As was discussed in Chapter I, one of the major assumptions of this research study was that both booms were to be installed on the KC-135. This assumption was made so that any logistics support cost differences could be identified with the peculiar boom system design and not be obscured by different aircraft, force sizes, or utilization programs. Therefore, the weapon system level variables are the same for both boom systems. Table VIII on page 132 lists the weapon system variables used in both the AARB and the KC-135 boom analyses.

Table VIII
Values for Common Weapon System Variables*

VARIABLE	BRIEF DESCRIPTION	VALUE	SOURCE** OF DATA
TFFH	Total Force Flying Hours	2,400,000	R
PFFH	Peak Force Flying Hours	60,000	R
PIUP	Program Inventory Usage Period	10	R
M	Number of Operational Bases	36	G033
OS	Fraction of Force Deployed Overseas	.071	G033
EBO	Standard for Expected Backorders	.10	R
NSYS	Number of Systems in Weapon System	1	R

* Only those parameters that are true variables are presented here. Those variables that have standard values that do not vary between weapon systems are not presented here.

** Data Sources and Codes: G033BQI3B G033
Researchers R

The variables that have government-furnished standard values have been omitted. For a complete description of all of the variables refer to Appendix A. For an explanation of how the values were selected refer to Chapter III.

Determination of values for AARB system variables. Table IX on page 133 lists the system peculiar variables used in both the AARB and the KC-135 boom analyses and their corresponding values. The system variables that have government-furnished standard values have been omitted. Those variables with values that differ between the systems are discussed in the following paragraphs. Explanations for the KC-135 values can be found in Chapter III.

Table IX
Values for AARB and KC-135 Boom System Variables

VARIABLE	BRIEF DESCRIPTION	AARB VALUE	KC-135 VALUE
SHQ	Hours of Scheduled Maintenance Per Quarter	8,200	8,200
SECOST	Total Cost of all Support Equipment	2,160,000	0
N	Number of FLUs in the System	12	15
FB	Cost of New Base Facilities	0	0
FD	Cost of New Depot Facilities	0	0
H	Number of Pages of New Technical Data	2,127	0
TCB	Cost to Train One Refueling Specialist	6,931	6,931
TCA	Cost to Train One Avionics Specialist	17,146	0
MENB	Number of Inflight Refueling Specialists	5	5
MENA	Number of Avionics Specialists	1	0
KTYP	Dummy Variable Indicating Type of System	1	135
TE	Cost of New Training Equipment	0	0

FB and FD. The cost of new base and depot facilities (FB and FD respectively) required to support the AARB system were considered to be zero. It was assumed that existing facilities were more than adequate to support the deployment of AARBs on KC-135 aircraft.

H. The number of new, original contractor-prepared reproducible pages of technical data was considered to be 2127 pages. This equals the number of pages of existing KC-135 boom system related technical data. There was no reason to expect that any more or any less technical data would be required for the AARB system. The following

reference numbers listed in the bibliography pertain to KC-135 boom system technical data: 77, 78, 79, 80 and 81.

KTYP. The value for this dummy variable, in the AARB analysis, is "1." For a discussion of the variable refer to page 81 in Chapter III.

MENB, MENA, TCB, and TCA. These variables were defined to approximate the cost of training the men required to maintain the boom system. It was estimated that the AARB system would require the same base refueling shop maintenance manning level as is now required in typical KC-135 base refueling maintenance shop (MENB = 5). In addition, it was estimated that the AARB system would require one additional man in the base avionics maintenance shop (MENA = 1) to handle the additional workload required for the FBWS. For a discussion of TCB and TCA, the costs of training inflight refueling and avionics specialists respectively, refer to page 83 in Chapter III.

N. The number of FLUs in the AARB system which were used in the analysis (N) was 12. The number was developed during this analysis.

SECOST. The total cost of all base support equipment (SECOST) required for the KC-135 was obtained from the 301st Field Maintenance Squadron Inflight Refueling Shop. These costs were considered to be sunk costs, that is, already expended for the KC-135 boom system and not likely to be required again in the next ten years. For the AARB, a figure for the support equipment required at the base was estimated

at three times the cost of the equipment required for the KC-135 boom or $60,000 per base. This estimate was selected because it was assumed that support equipment, similar to the equipment required for the KC-135 boom, would have to be purchased at current-day prices. It was also assumed that some type of special electronic test equipment would be required for the FBWS. A more accurate figure could not be estimated because, to the best of the researchers' knowledge, support equipment requirements have not been established. Therefore, the total cost of support equipment required at base level, or SECOST, equals $2,160,000 for (M) bases.

SHQ. The quarterly number of scheduled maintenance hours on the AARB system (SHQ) was assumed to be equal to the number of hours required for the KC-135 boom system.

Determination of values for AARB FLU variables. The values for the Boom Model variables used for the AARB FLUs were estimated by engineering and logistics personnel in the ATCA SPO. These offices were supplied the values derived by the researchers for the corresponding KC-135 FLU variables, if they existed. Then using the preliminary design studies for the most part, accumulated experience, and the KC-135 baseline values, engineering estimates were made of the values to be expected for the AARB. These SPO supplied values were then used in the Boom Model to determine the logistics support cost figure of merit for the AARB.

The values for the FLU level AARB variables are listed in Appendix D. For comparative purposes, the KC-135 boom values are also listed in the same appendix.

After all of the data on the AARB was collected, the data was fed into the Boom Model computer program. A computer printout of the resulting AARB logistics support cost analysis is shown in Appendix F. The corresponding KC-135 boom logistics support cost analysis printout is shown in Appendix E, and both of them are explained in the next section.

Logistics Support Cost Analyses

Table X on page 137 lists the eight Boom Model equations and Table XI on page 138 shows the logistics support cost comparisons for all of the AARB and KC-135 boom FLUs. The FLUs are listed in the left column of Table XI and the applicable system, AARB or 135, is listed in the second column. The next eight columns show the contributions to the logistics support cost of each FLU, by each Boom Model equation, and the final column shows the total logistics support cost contribution of each FLU.

The costs, which are rounded to the nearest $1000, are also displayed in Appendices E and F for the KC-135 boom and the AARB respectively.

Table X Boom Model Equations	
EQUATION	DESCRIPTION
C_1	The Cost of Initial and Replacement Spares
C_2	The Cost of On-Equipment Maintenance
C_3	The Cost of Off-Equipment Maintenance
C_4	The Cost of Inventory Entry and Supply Management
C_5	The Cost of Support Equipment
C_6	The Cost of Personnel Training and Training Equipment
C_7	The Cost of Records Management and Technical Data
C_8	The Cost of New Facilities

The FLU-by-FLU, equation-by-equation, logistics support cost comparison shown in Table XI on page 138 and the FLU ranking and logistics support cost contributions shown in Table XII on page 139, are analyzed further in the following paragraphs, as to their impact on the 10 year costs.

<u>Rolling Pivot and Boom Fork Assemblies</u>. In both boom systems, the pivot assembly accounted for less than one percent of the total logistics support cost figure of merit. However, the cost of the rolling pivot assembly of the AARB was $67,000 higher than the cost of the KC-135 boom fork assembly. The primary factor in this increase was a $57,000 increase in equation C_4 due to the number of new parts introduced into the supply system and the recurring management costs associated with them.

Table XI
AARB and KC-135 Boom FLUs:
Logistics Support Cost Comparison by Equation

		BOOM MODEL EQUATIONS								
FLU NOUN		C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	TOTAL
Rolling Pivot	AARB	10	6	10	71	0	0	0	0	97
Boom Fork	135	1	6	8	14	0	0	0	0	30
Control Surfs	AARB	75	76	438	14	0	0	9	0	612
Ruddevatorss	135	0	33	214	14	0	0	4	0	265
Fly-By-Wire	AARB	4175	31	2960	71	0	0	21	0	7259
	N/A									
Actuators	AARB	330	254	585	29	0	0	17	0	1214
Boost Units	135	0	83	89	14	0	0	6	0	192
Sensors	AARB	1505	729	7	14	0	0	52	0	2308
Transmitters	135	108	150	2	14	0	0	11	0	285
Nozzle	AARB	3015	625	1986	100	0	0	63	0	5790
	135	0	285	436	14	0	0	29	0	765
Signal Coil	AARB	34	74	0	15	0	0	4	0	127
Amplifier	135	99	217	0	14	0	0	12	0	343
Tailcone	AARB	210	25	783	14	0	0	4	0	1035
	135	120	74	1482	14	0	0	7	0	1698
Gland Seal	AARB	2	12	0	14	0	0	0	0	29
	135	3	47	0	14	0	0	2	0	66
Surge Boot(s)	AARB	29	6	2	15	0	0	0	0	52
	135	49	23	3	14	0	0	2	0	91
Ext/Ret Shock	AARB	30	16	69	29	0	0	2	0	146
Absorbers	N/A									
Extension	AARB	17	23	290	43	0	0	2	0	375
Drive Unit	135	0	33	420	14	0	0	2	0	470
Ruddevator	N/A									
Quadrant	135	152	113	1	14	0	0	6	0	285
Ruddevator	N/A									
Lock Roller	135	10	63	1	14	0	0	30	0	117
Elevation	N/A									
Control Unit	135	51	94	53	14	0	0	4	0	215
Azimuth	N/A									
Control Unit	135	5	28	13	14	0	0	3	0	62
Telescope	N/A									
Control Unit	135	8	19	12	14	0	0	1	0	54
TOTALS	AARB	9432	6149	7132	429	2160	7403	643	0	33350
	135	605	5543	2733	213	0	4417	118	0	13330

NOTES:
1. Costs shown are in thousands of dollars and are rounded off.
2. Individual row entries may not sum to the totals because of round-off error.
3. Equations C_5 and C_6 represent system level costs which are not accumulated by FLUs.

Table XII
Comparison of AARB and KC-135 Boom FLUs:
Logistics Support Cost Contribution and Rankings

WUC	NAME OF FLU	AARB RANK	AARB LSC CONTRIBUTION ($1000)	AARB %	KC-135 RANK	KC-135 LSC CONTRIBUTION ($1000)	KC-135 %
46755	Fly-By-Wire System	1	$7,259	22		N/A	
46771	Nozzle	2	5,790	17	2	$ 765	06
51921	Sensors/Transmitters	3	2,308	07	6	285	02
46794	Actuators	4	1,214	04	9	192	01
46772	Tailcone	5	1,035	03	1	1,698	13
46766	Flight Control Surfaces	6	612	02	7	265	02
46778	Extension Drive Unit	7	375	01	3	470	04
46765	Ext/Ret Shock Absorbers	8	146	00		N/A	
46851	Signal Coil Amplifier	9	127	00	4	343	03
4676B	Pivot Assemblies	10	97	00	15	30	00
46773	Surge Boot(s)	11	52	00	11	91	01
4676H	Sliding Gland Seal	12	29	00	12	66	00
46768	Ruddevator Quadrant		N/A		5	285	02
46857	Elevation Control Unit		N/A		8	215	02
4676A	Ruddevator Lock Roller		N/A		10	117	01
4685A	Azimuth Control Unit		N/A		13	62	00
46854	Telescope Control Unit		N/A		14	54	00
	CONTRIBUTION OF ALL FLUs			57			37

Flight Control Surfaces and Ruddevators. In both boom systems, the flight control surfaces accounted for two percent of the total logistics support cost figure of merit. However, the cost of the AARB flight control surfaces was \$347,000 higher than the KC-135 boom ruddevators for several reasons: (1) equation C_1 increased by \$75,000 as a result of filling base and depot repair pipelines, (2) equation C_2 increased by \$43,000, (3) equation C_3 increased by \$224,000. The increases are due primarily to the increased quantitiy per assembly (QPA).

Fly-By-Wire Control System. It ranked first in the AARB system. This was a new, and as yet, not completely defined system. All FLU parameter values were very rough guesses. It is not surprising that it turned out to be the most costly FLU because of the number of complex components, and the advanced technology represented by the system. A high unit cost is expected to result from these factors.

Actuators and Boost Units. The approximately \$1 million increase in the contribution of the AARB servo-actuators, over the KC-135 boom ruddevator boost units, was primarily the result of large increases in equations C_1, C_2, and C_3. The \$330,000, \$171,000, and \$496,000 increases in C_1, C_2, and C_3 respectively can be attributed to a higher unit cost and an increase in QPA from 2 to 6. The increases in the maintenance equations--C_2 and C_3--can also be attributed to a decrease in the fraction of units that are reparable at base

level (RTS) and a corresponding increase in the fraction of units that are not reparable at base level (NRTS).

Sensors and Transmitters. The approximately $2 million increase in the contribution of the AARB sensor package, over the KC-135 boom position transmitters, can be primarily attributed to the higher unit cost and the increase in QPA from 3 to 16. The bulk of the increase occurred in equation C_1 where the approximately $1.4 million increase is due to replacements for these expendable sensors. Equation C_2 increased by approximately $600,000 also, as a result of the higher QPA.

Nozzle. The approximately $5 million increase in the contribution of the AARN, over the KC-135 nozzle, can be attributed to a greater than $3 million cost to fill the repair pipelines and a $1.55 million increase in off-equipment maintenance. The doubled unit cost and positive condemnation rate was a factor in both equations. Other factors involved in the increase in equation C_3 were depot repair costs, repair man-hours, and a larger cost to repair lower level assemblies.

Signal Coil Amplifier. The $216,000 decrease in the contribution of the AARB signal coil amplifier system, under the KC-135 signal coil amplifier system, can be attributed to the trebled increase in mean time between failures.

Tailcone. The $663,000 decrease in the contribution of the AARB tailcone, under the KC-135 tailcone, can be mainly attributed to a $700,000 decrease in off-equipment

maintenance cost as a result of a two fold increase in MTBF. The decrease was aided by a drop in on-equipment maintenance costs which occurred for the same reason; however, the decrease was partially offset by the increased cost of filling the repair pipelines and replacing condemned tailcones with higher cost tailcones.

Gland Seal. The gland seal contributed less than one percent of the logistics support costs to each boom system. However, the AARB gland seal contributed $37,000 less than did the KC-135 boom gland seal. The decrease is almost solely a function of the reduced off-equipment maintenance cost resulting from a quadruple MTBF increase.

Surge Boot(s). In both boom systems, the surge boot(s) contributed little to the total costs of the systems. However, the AARB surge boot contributed $39,000 less than did the KC-135 boom surge boots. The decreases occurred in equations C_1, C_2, and C_3 and they resulted mainly from doubling the MTBF.

Extension and Retraction Shock Absorbers. These shock absorbers (WUC 46765) were peculiar to the AARB. Like the FBWS, these shock absorbers were not completely defined for this analysis and therefore the values for all the FLU parameters were very rough estimates.

Extension Drive Unit. The $95,000 decrease in the contribution of the AARB telescoping drive unit, under the KC-135 unit, was due mainly to a $130,000 decrease in off-equipment maintenance. The important factor in this decrease

was the 50 percent increase in MTBF. This increase in MTBF also helped decrease the cost of on-equipment maintenance. However, these decreases were offset by a $17,000 increase in equation C_1 due to filling the depot repair pipeline, and a $29,000 increase in equation C_4 due to entering the new items into the inventory.

There were five other FLUs that were included in the KC-135 boom logistics support cost analysis which had no corresponding FLUs in the AARB. These five FLUs are the last five FLUs shown in Table XII. Together they accounted for $734,741 and 5 percent of the logistics support cost of the system.

Table XIII shows the same information that is displayed in Table XII for the KC-135 boom FLUs; however, the 15 FLUs are listed in decreasing order by logistics support cost contribution. This allows visibility of the FLUs within the system. In Table XII, the AARB FLUs are listed in decreasing order by logistics support cost contribution.

Table XIII
Contribution and Ranking of KC-135 Boom FLUs

RANK	FLU	NAME OF FLU	LSC CONTRIBUTION OF FLU	FRACTION OF SYSTEM LSC
1	46772	Tailcone	$1,697,684	.13
2	46771	Nozzle	764,910	.06
3	46778	Extension Drive Unit	469,634	.04
4	46851	Signal Coil Amp.	343,316	.03
5	46768	Ruddevator Quadrant Assembly	285,232	.02
6	51921	Position Transmitters	284,838	.02
7	46766	Ruddevators	265,331	.02
8	46857	Elevation Control Unit	215,426	.02
9	46794	Ruddevator Boost Units	191,761	.01
10	4676A	Lock Roller Assy.	117,470	.01
11	46773	Surge Boot	90,582	.01
12	4676H	Sliding Gland Seal	66,230	.00
13	4685A	Azimuth Control Unit	62,355	.00
14	46854	Telescope Control Unit	54,258	.00
15	4676B	Boom Fork Assy.	30,094	.00

Chapter Summary

The AARB has several design improvements which are likely to reduce costs.

1. Increased controllability throughout a larger refueling envelope.

2. Improved electrical continuity in the signal coil system.

3. Increased service life of the sliding gland seal.

4. Improved design of the surge boot.

Several aspects of the AARB design have the potential of adding greatly to the cost of supporting the system. The most notable of these is the fly-by-wire control system. This feature will add many expensive components including sensors, black boxes, wiring, switches and transmitters. The logistics support cost performance will depend largely on the reliability of the system. The complexity of the control system is also likely to result in increased training costs and the addition of high-cost support equipment.

The nozzle, which includes the added complexity required for the independent disconnect capability, will also likely add significantly to the logistics support cost of the AARB.

These analyses resulted in a logistics support cost figure of merit for the AARB of $33.35 million and a logistics support cost figure of merit for the KC-135 boom of $13.33 million. The significance is not in the totals, but that the AARB will cost approximately $20 million more to support over the next ten years than will the KC-135 boom. In fact, the AARB is more costly in every cost category.

The next chapter describes the sensitivity analyses that were conducted on selected AARB parameters in order to test the impact of uncertainty of the variable values on the total logistics support cost figures of merit.

V. Sensitivity Analysis

As was explained in Chapter IV, a great deal of uncertainty existed in the values for the AARB FLU variables. This is to be expected during the early stages of a program. Indeed, the information available on the AARB consisted only of preliminary design reports; many of the details were sketchy at best.

Although crude, the estimates of the values for the AARB logistics support cost variables were based on the best information available at the time of this study. Developing a support cost estimate of this kind is necessarily an evolving process, gaining refinement at every step as newer and better information becomes available.

The Sensitivity Analysis

Given the uncertainty of the preliminary information, it was decided to test the sensitivity of the logistics support cost figure of merit to changes in the values of some of the key input variables. It was felt that the analyses would assist in identifying the relative importance of the variables to the overall logistics support cost figure of merit. In addition, such analyses could assist in identifying the limits of the values for selected parameters, beyond which excessive costs would result. Furthermore, such analyses could indicate cost and performance tradeoffs that would assist managers in meeting logistics support cost thresholds. If an estimate of the cost of improving a particular parameter

value can be made, sensitivity analysis can help evaluate the economic feasibility of the additional work. In this study, sensitivity analyses were conducted mainly to investigate the effects of the uncertainty of the values for the AARB variables. The results highlighted some areas where attention should be directed toward both controlling the parameter values and accurately determining them.

Minimizing logistics support cost quickly focuses on the cost of maintenance. Reducing maintenance cost requires increasing MTBF, and/or making repairs less costly. Factors affecting the cost of repair are the time and skill levels required, and whether components and subassemblies are reparable or must be replaced. Trade-offs are necessary, and some of the options have complex effects on the final life cycle cost. For example, reparable items are more expensive to acquire; however, if the MTBF is very low, meaning frequent repairs are needed, it would probably be less expensive to repair an item than it would be to replace the item with every failure--as would occur if the part were expendable. On the other hand, if MTBF can be increased substantially, it may prove cheaper to discard the item than to maintain an expensive repair capability.

Some of the variables tested in the sensitivity analysis were chosen because they were known to have a significant effect on logistics support costs, and it was desired to observe the effects of errors in the estimates. Examples of this kind of variable are MTBF and Unit Cost. Others were

chosen because of the uncertainty that existed in both the estimates and the concepts. Two such variables were EBO and BMC. They were particularly difficult to estimate with any degree of confidence.

The logistics support cost contribution of any FLU. The logistics support cost contribution of any FLU is the sum of the costs calculated by equations C_1, Cost of FLU Spares; C_2, Cost of On-Equipment Maintenance; C_3, Cost of Off-Equipment Maintenance; C_4, Cost of Inventory Entry and Supply Management; and C_7, Cost of Records Management and Technical Data. The contribution excludes the weapon system and system costs of personnel training, support equipment, and new facilities.

The Results of the Sensitivity Analyses

Two types of variable changes were investigated. In the first type, variations were made across all FLUs at the same time, either by changing a weapon system variable, or by making the same change in a FLU variable for all FLUs simultaneously. In the second type of sensitivity analysis, the values of single variables in single FLUs were varied one at a time. The results of the sensitivity analyses are displayed in Tables XIV and XV.

Table XIV, on page 150, shows the results of changing the values across all FLUs. The logistics support cost figures of merit for the KC-135 and AARB FLUs, as derived using the estimated values for the input variables, are shown

Table XIV
Sensitivity Analysis--Simultaneous Changes for all FLUs

	TOT LSC	1st RANK FLU	LSC OF FLU	2nd RANK FLU	LSC OF FLU	3rd RANK FLU	LSC OF FLU	4th RANK FLU	LSC OF FLU	5th RANK FLU	LSC OF FLU
KC-135 LSC*	13.33	Tail-Cone	1.70	Nozzle	.76	Ext Drive	.47	Signal Coil Amp	.34	Rud Quad	.29
AARB LSC*	33.35	FBWS	7.26	Nozzle	5.79	Sen-sors	2.31	Servos	1.21	Tailcone	1.04
AARB Sensitivity Runs: AARB EBO X .5**	34.43	FBWS	8.16	Nozzle	5.79	Sen-sors	2.31	Servos	1.21	Tailcone	1.04
AARB EBO X 1.5+	33.35	FBWS	7.76	Nozzle	5.79	Sen-sors	2.31	Servos	1.21	Tailcone	1.04
AARB EBO X 3	32.63	FBWS	7.25	Nozzle	5.25	Sen-sors	2.31	Tailcone	1.04	Servos	1.03
AARB MTBF X .5	51.34	FBWS	14.39	Nozzle	10.93	Sen-sors	4.60	Servos	2.22	Tailcone	2.06
AARB MTBF X .25	88.40	FBWS	28.70	Nozzle	21.72	Sen-sors	9.19	Tailcone	4.62	Servos	4.40
AARB MTBF X 1.5	27.88	FBWS	5.15	Nozzle	4.27	Sen-sors	1.54	Servos	.88	Tailcone	.70
AARB BMC X .5	33.12	FBWS	7.23	Nozzle	5.61	Sen-sors	2.31	Servos	1.20	Tailcone	1.03
AARB BMC X 1.5	33.57	FBWS	7.28	Nozzle	5.97	Sen-sors	2.31	Servos	1.23	Tailcone	1.04

* Logistics support cost figures of merit and contributions of FLUs using the data in Chapters III and IV.
** This change resulted in one additional FBWS and one additional flight control surface being stocked at each base.
\+ No change.

for comparison in the first two rows of the table. Sensitivity was checked by varying the values of the variables by the amounts shown in the left column. The cost ranking and the magnitude of the logistics support cost contribution of the four highest cost AARB FLUs is displayed in Table XIV for each of these blanket variable changes.

Table XV, on pages 155 through 157, displays the relative effects on the logistics support cost ranking of the top three FLUs when individual FLU variables were changed by the amounts indicated in the left column. Only the top three FLUs were checked in this fashion. These three were considered to be of most interest to this analysis because they contributed so heavily to the overall LSC figure as to largely mask the effects of changes in the other FLUs. The effects of varying the input parameters was found to be quite similar between FLUs.

<u>Standard for Expected Backorders (EBO)</u>. There is no established standard for numbers of backorders in the Air Force. A standard is established by the modeler to introduce a desired level of supply performance, for calculation of initial base repair pipeline spares.

As discussed in reference to equation C_1 in Chapter II, page 29, the LSC Model uses a Poisson approximation to calculate the required number of base level spares. That calculation involves the standard established for expected backorders (EBO), the mean demand rate per base, and the weighted base repair pipeline time. The lower the value of

EBO, the greater the number of spares that must be stocked in order to insure that the backorder standard is not exceeded. Consequently, the logistics support cost went up when EBO was decreased and went down, as expected, when EBO was sufficiently increased.

When EBO was cut by fifty percent, the entire change was reflected in the fly-by-wire system (FBWS) components and the flight control surfaces. Keeping in mind that additional stockage can only occur in discrete units, a level of one each additional stock of these items was computed for every base. On the other hand, a fifty percent increase in EBO was not enough to change the number of spares computed for any of the FLUs. Therefore, the total logistics support cost stayed the same and the contribution of each FLU also remained constant.

In an attempt to gain some feel for what values of EBO might reflect actual field conditions, the writers collected the actual numbers of backorders existing across nine KC-135 boom FLUs on one day. This was done by calling the item managers for the FLUs at the depot. This total number of backorders was divided by the number of FLUs and the number of bases to give an instantaneous average number of backorders per FLU per base. The value thus obtained was 0.30 which is three times the value estimated of 0.10. This value was used for one of the sensitivity runs (3 X EBO in Table XIV). The result was a computation of 1 spare each for the nozzle and fly-by-wire system at each base. Several

KC-135 bases were called in order to verify how well the model predicted the base stock level, assuming that 0.30 was a reasonable estimation of EBO. What was found was that the situation in the field is not predicted by the model and probably could not be without the use of a much more complex model.

In general, each base has a spare boom and a spare nozzle from which parts are cannibalized. In addition, there is good stockage of several items of an essential nature which experience frequent demands, such as the tailcone and the gland seal kit. The model would have had to predict at least one spare for each FLU to have adequately reflected a spare boom at each base. It is presumed by the writers that the backorders reported by the item managers, as described in the previous paragraph, represent demands to replace insurance type spares, such as parts for the spare booms that had to be used, rather than aircraft which are lacking essential boom parts and cannot perform their mission.

Mean Time Between Failures (MTBF). The key to reducing the cost of maintenance is to reduce the number of repairs required and the cost of performing the repairs once they become necessary. MTBF is a reliability parameter which is used to estimate the number of failures of a FLU. It appears in four of the Boom Model equations and is therefore one of the most significant parameters in the logistics support cost analysis. The sensitivity of the logistics support costs to changes in MTBF was tested, as shown in Table XIV on page 150,

by varying the MTBFs of all FLUs simultaneously by .25, .50, and 1.5 times the base value. Each value was used for one test.

When MTBFs were decreased, the logistics support costs increased. When all the MTBFs were decreased by 50 percent, the total logistics support cost increased by 54 percent, and the logistics support cost contribution of each FLU approximately doubled. When the MTBFs were reduced to 25 percent of the base value the total logistics support cost increased by 165 percent, and the contribution of each FLU approximately quadrupled. When MTBFs were increased by a factor of 1.5, the total logistics support cost decreased by only 16 percent.

Of course, the same results occurred when individual FLU MTBFs were varied, except that the affects were limited to the FLU. As shown in Table XV, on pages 155 through 157, individual MTBF changes, of the magnitudes shown, can have a considerable affect on the relative logistics support costs of the FLUs.

BMC. BMC is multiplied by the FLU unit cost in equation C_3, the Costs of Off-Equipment Maintenance, to give an average dollar cost per failure for the repair of lower level assemblies and components. As explained in Chapter III, the writers developed an original method of estimating this variable, based on reported off-equipment maintenance actions. This method had the attraction of being somewhat more objective than the previous method of pure estimation, in that it

Table XV (Part 1 of 3)
Sensitivity Analysis--Fly-By-Wire System (FBWS)

CONDITION TESTED	LSC FIG. OF MERIT	LSC OF FBWS	FBWS RANK
AARB Estimated Data	33.35	7.26	1
FBWS MTBF X 0.5	40.49	14.40	1
FBWS MTBF X 0.25	54.79	28.70	1
FBWS MTBF X 2	30.22	4.13	2
FBWS MTBF X 3	29.17	3.08	2
FBWS COND = 0, RTS = 0.2	33.43	7.34	1
FBWS COND = 0, NRTS = 0.815	33.53	7.44	1
FBWS UC = $35,000	35.04	8.95	1
FBWS UC = $15,000	31.66	5.57	1
FBWS Hours X 0.5	33.32	7.23	1
FBWS Hours X 2	33.40	7.31	1
FBWS DMX X 0.5	32.04	5.96	1
FBWS DMX X 1.5	34.64	8.55	1

NOTES:
1. Costs, in millions of dollars, are rounded to two decimal places.
2. The LSC contribution of the nozzle was $5.79 million for all conditions shown.
3. The LSC contribution of the sensors was $2.31 million for all conditions shown.

Table XV (Part 2 of 3)
Sensitivity Analysis--Nozzle

CONDITION TESTED	LSC FIG. OF MERIT	LSC OF NOZZLE	NOZZLE RANK
AARB Estimated Data	33.35	5.79	2
Nozzle MTBF X 0.5	38.48	10.93	1
Nozzle MTBF X 0.25	49.28	21.72	1
Nozzle MTBF X 2	30.51	2.95	2
Nozzle MTBF X 3	29.75	2.19	3
Nozzle COND = 0, RTS = 0.8	32.44	4.88	2
Nozzle COND = 0, NRTS = 0.21	32.53	4.97	2
Nozzle UC = $20,000	34.47	6.91	2
Nozzle UC = $10,000	32.23	4.67	2
Nozzle Hours X 0.5	32.73	5.17	2
Nozzle Hours X 2	34.59	7.03	2
Nozzle DMX X 0.5	32.90	5.34	2
Nozzle DMX X 1.5	33.80	6.24	2

NOTES:

1. Costs, in millions of dollars, are rounded to two decimal places.
2. The LSC contribution of the FBWS was $7.23 million for all conditions shown.
3. The LSC contribution of the sensors was $2.31 million for all conditions shown.

Table XV (Part 3 of 3)
Sensitivity Analysis--Sensor Package

CONDITION TESTED	LSC FIG. OF MERIT	LSC OF SENSORS	SENSORS RANK
AARB Estimated Data	33.35	2.31	3
Sensors MTBF X 0.5	35.64	4.60	3
Sensors MTBF X 0.25	40.23	9.16	1
Sensors MTBF X 2	32.20	1.16	4*
Sensors MTBF X 3	31.82	.78	5**
Sensors COND = .75	32.99	1.95	3
Sensors UC = $450 each	33.78	2.74	3
Sensors UC = $250 each	32.92	1.88	3
Sensors Hours X 0.5	32.98	1.94	3
Sensors Hours X 2	34.08	3.04	3

NOTES:
1. Costs, in millions of dollars, are rounded to two decimal places.
2. The LSC contribution of the FBWS was $7.26 million for all conditions shown.
3. The LSC contribution of the nozzle was $5.79 million for all conditions shown.
4. The LSC contribution of the servos was $1.21 million for all conditions shown.

* Servos third ranked at $1.21 million.

** Servos third ranked at $1.21 million. Tailcone fourth ranked at $1.04 million.

was based on reported data. However, although the method had intuitive appeal, the figures obtained were no more verifiable than if they had been pure guesses. For this reason, a range of values was tested to see the magnitude of the effects of error in this variable.

The effects of variation in BMC were tested by changing the estimated values by plus and minus 50 percent. As can be seen in Table XIV, on page 150, the effect was relatively minor. The total logistics support cost changed by plus and minus 0.7 percent. As expected, all of this change occurred in equation C_3.

Changes in BMC did not affect the logistics support cost figures for any of the nonreparable (expendable) items. For these items, RTS (reparable this station) equals zero, NRTS (not reparable this station) equals zero, and COND (base condemnation rate) is 1.00. The effect of RTS and NRTS being zero is for all of the terms of equation C_3 to drop out, except for the term that accounts for the cost of shipping replacements for the base condemned items. None of the BMC changes was great enough to cause a change in the logistics support cost ranking of the FLUs.

<u>Condemnation Rate (COND)</u>. When an item is removed from the aircraft, it is either determined to be reparable this station (RTS), not reparable this station (NRTS), or it is condemned (COND). A base level condemnation rate of zero was tested for the fly-by-wire system (FBWS) and the nozzle. Condemnations for these items were estimated by the ATCA SPO

to be .015 and .01 respectively. The writers felt that these values were too high since expensive, reparable assemblies are very seldom condemned at the base level--the condemnation rate for the KC-135 nozzle is zero. The variation of this variable was tested in three ways. First, it was assumed that the fraction of removed FLUs formerly estimated to be condemned at base level (COND), would now be reparable this station (RTS). In other words, RTS was increased by the same amount that COND had to be reduced to equal zero. Surprisingly, the logistics support cost of the fly-by-wire system increased slightly. This was found to be due to the effect of the increase in RTS which is used in the calculation of the weighted pipeline time, which in turn is used in the calculation of base repair pipeline spares. The effect was to increase the stockage of fly-by-wire system components by one at each base. This overshadowed the effect of the decreased condemnations. There was also the small increase in off-equipment maintenance. The LSC of the nozzle decreased by about 16 percent when the condemnation rate was zero due to the effect of the eliminated condemnations.

A second kind of variation in COND reflecting perhaps a different repair policy was investigated by letting NRTS pick up the amount that COND was reduced to equal zero. For the fly-by-wire system, the LSC increased by $180,000 or about 0.5 percent. The effect of this change was for the depot and base pipeline spares to increase, again overshadowing the drop in condemnation spares. Also,

off-equipment maintenance cost showed a slight increase due to the increase in NRTS. When this same change was made for the nozzle, decreasing COND from 0.01 to zero and increasing NRTS from 0.20 to 0.21, the LSC went down by $820,000 or 2.5 percent. This change was largely in the replacement spares no longer required because of COND being equal to zero. There was a lesser rise in depot spares and off-equipment maintenance and no change in base repair pipeline spares.

As explained earlier, the effects of RTS, NRTS and COND are interrelated. This fact complicates the investigation of the effects of changes in these variables. If the condemnation rate of a reparable item is decreased, lowering the cost of replacement spares required, the effect will be offset by the resulting increase in base or depot level repair costs because RTS or NRTS will be increased by the amount that COND is decreased. Whether RTS or NRTS are increased depends upon repair level policy decisions, and the ramifications apply to support equipment and facilities required as well as training costs for repair personnel and transportation charges for parts shipped between the bases and the depot. A detailed repair level analysis is beyond the scope of this thesis.

Unit Cost (UC). Unit cost is not only of interest in considering initial acquisition cost. It also determines how much will be paid for spares and lower level assemblies. For this reason, unit cost appears as a multiplier in the spares

computations in equation C_1, and in C_2, the equation for the cost of off-equipment repairs.

The unit cost was varied to see what the effect of errors in its value would be on the logistics support cost contribution of the FLUs. Varying the unit cost of the fly-by-wire system by plus and minus 40 percent, from $15,000 to $35,000, caused the logistic support contribution of the fly-by-wire system to change by plus and minus 23 percent, as shown in Table XV. The unit cost of the nozzle was varied between $10,000 and $20,000, a 33 percent change either side of the estimated $15,000 cost. These changes caused the logistics support cost contribution of the nozzle to vary by plus and minus 19 percent. The unit cost of the sensors was varied by $100 either side of the estimated cost of $350, and the logistics support cost of the sensors varied by plus and minus 19 percent. As can be seen, the effect of unit cost on the FLU logistics support cost is great. The logistics support cost figure of merit will take on increased usefulness and validity only as unit costs and MTBFs become known more precisely.

<u>Average maintenance man-hours required (IMH, RMH, and BMH)</u>. The importance of the frequency of repairs to logistics support cost was stressed in the discussion on MTBF earlier in this chapter. Another factor is the cost of each repair action which will, in most cases, be largely determined by the average man-hours to perform repairs.

A sensitivity check was performed on the estimated average hours to perform remove and replace actions (RMH), on-equipment maintenance actions (IMH), and off-equipment maintenance actions (BMH). For the fly-by-wire unit, the hours were halved, and a 0.4 percent drop in the logistics support cost contribution of the unit resulted. The hours were then doubled to give a .7 percent increase. Similarly, the nozzle logistics support cost contribution dropped by 10.7 percent when the hours were cut in half and increased by 21.4 percent when they were doubled. The same changes were made to the sensor package maintenance man-hours. However, this FLU experienced a 16 percent decrease when the hours were cut and a 32 percent increase when the hours were increased. The relatively greater magnitude of the changes for this FLU is due to the higher number of sensors (16) included in the AARB system. The relatively small change in the fly-by-wire system logistics support cost can be explained by the fact that the base repair times for this FLU were estimated to be realtively lower to begin with. In fact, base level maintenance cost of this FLU is overshadowed by the cost of spares and depot maintenance.

<u>Average depot repair cost (DMX)</u>. The average depot repair cost gives the average cost to repair each item sent to the depot for overhaul (NRTS). This variable could be more or less important then the cost of base level repairs to the logistic support cost (depending on the repair level policy).

The value estimated for DMX for the fly-by-wire system was $1500. Sensitivity was checked by trying values 50 percent above and below this value to see the corresponding range of the logistics support cost figure of merit. When DMX was cut in half, the logistics support cost contribution of the fly-by-wire system decreased by 18 percent to $5.96 million. When DMX was increased by 50 percent, the fly-by-wire system contribution also increased by 18 percent, to $8.55 million. For the nozzle, a plus and minus 50 percent change in DMX, caused the logistic support cost of the nozzle to change by plus and minus 7.7 percent. The larger change for the fly-by-wire unit is explained by the high NRTS rate (.80) for that FLU. DMX is always zero for expendable items and consequently the sensor package was not tested for sensitivity.

<u>Chapter Summary</u>

It appears that the most promising logistics support cost improvements can be made in the MTBFs of the FLUs. If one is to hold the line on cost, it is important to have as high an MTBF as is attainable within reasonable limits of development, production and support costs required to achieve that MTBF.

Unit cost is also an important parameter, especially if there is any substantial rate of condemnation. Depot repair cost can also be an important factor. Because of the high unit cost of reparable assemblies, this parameter

increases greatly if a sizeable number of condemnations occurs during depot overhaul.

These analyses have shown high cost FLUs of the AARB to be the fly-by-wire system and the advanced nozzle. The fly-by-wire system contains several major high cost components not found on the KC-135. The sensor package, which is the third highest cost FLU could also be considered a part of the fly-by-wire system because these 16 parts would not be required if there were no fly-by-wire system.

The major reason that the AARB nozzle cost is so much higher than the KC-135 boom nozzle is that this FLU includes the independent disconnect system. The independent disconnect system has no counterpart on the KC-135, and it adds complexity in an area where complexity is likely to be expensive. The nozzle receives the hardest usage of any part of the boom, as evidenced by the lowest MTBF of the KC-135 FLUs. The KC-135 boom nozzle is an essentially simple and very substantial component. It receives most of its damage as a result of contact with the receiver receptacle. The new nozzle will accommodate the release mechanism within the new, thinner nozzle wall; however, it will be subject to much the same abuse from contact with receiver receptacles. For this reason, the MTBF is not expected to improve greatly, if at all, over the KC-135 nozzle. There is a possibility, however, that some of the maintenance actions now reported against the KC-135 nozzle are actually due to signal coil problems, because the coil is imbedded in the wall of the nozzle. If so,

then the new nozzle may show some improvement because of the attention that has been given during development to improving the continuity of the signal coil circuit.

VI. Summary and Conclusions

This chapter contains a summary of the research performed for this thesis. The objective and methodology are briefly reiterated, followed by some conclusions and recommendations which resulted from this work.

Summary

The Advanced Aerial Refueling Boom (AARB) is being developed by the Douglas Aircraft Company as a possible subsystem for the Advanced Tanker/Cargo Aircraft and to demonstrate the feasibility of several advanced concepts for aerial refueling systems. The AARB is intended to overcome several limitations of the KC-135 boom, including a limited fuel flow capability and a relatively small envelope. Specifically, the AARB will incorporate the following design advances:

1. A larger refueling envelope that equals or exceeds the requirements of MIL-F-38363B(USAF), the military specification that defines the aerial refueling requirements.

2. Greater boom controllability because of a new, rolling pivot design and an improved control surface configuration.

3. The incorporation of a fly-by-wire control system.

4. An additional five feet of vertical separation between the tanker and the receiver, due to increased boom length.

5. An increased fuel flow rate during aerial refueling.

6. A redundant disconnect capability that is independent of proper operation of the refueling system in the receiver.

This research project was suggested by the ATCA System Program Office (SPO) as a first step toward bringing the costs of supporting the system into its decision framework. Logistics support cost figures of merit were to be developed using the Air Force Logistics Command Logistic Support Cost (LSC) Model, for both the KC-135 boom and for the AARB in order to estimate how much more or less it may cost to support the AARB in relation to the KC-135 boom. It was also desired that the estimated logistics support cost aspects of the AARB components be investigated in order to determine which could be expected to be the most costly to support.

The logistics support cost figures of merit for the two boom systems were developed and the cost contribution of each major component or First Line Unit (FLU) was identified. The major effort, however, was expended in developing the logistics support cost figure of merit for the KC-135 boom. The primary significance of this research effort was the methodology developed to obtain required data for use in estimating the logistic support costs of existing systems or subsystems--like the KC-135 boom system.

The scope of this research effort was limited in that no attempt was made to determine logistics support cost

figures of merit for either boom system as if it were an integral part of the ATCA. When a boom system is developed for the ATCA, updated logistics support cost analyses will have to be made. In that event, this research effort will provide a starting point and a methodology. Many logistics support costs are omitted from the LSC Model. Therefore, the temptation to look upon the logistics support cost figures of merit as the actual logistics support costs of the systems must be avoided. In fact, the estimates are only meaningful when compared with other similarly derived estimates. In order to better approximate the logistics support costs of the systems under consideration, and to facilitate the use of available data, the LSC Model was tailored to fit the particular situation being analyzed.

The Boom Model was adapted for this analysis from the LSC Model. It contains approximately fifty percent fewer variables and twenty-five percent fewer statements than the LSC Model. Some of the changes that were made to the LSC Model were the direct results of the inability to gather reasonable data on an existing weapon system for the LSC Model variables. Other changes were made in order to simplify portions of the equations which were felt to be unnecessarily complicated. Since the logistics support cost analyses involved comparing an existing and a proposed system, some equations had to be changed to account for the peculiar situation applicable to each weapon system. For example, some of the costs, such as pipeline spares and initial training

costs, are sunk costs for the KC-135 boom system. The computer program, therefore, had to be changed so that the equations for these types of costs would be computed differently for the two systems.

The methodology. Very little published information was found indicating the techniques or the sources of data required for the LSC Model. Most of the guidance found was word-of-mouth from previous users of the model. It is the intention of the writers that the methodology developed herein provide a useful guide for succeeding LSC Model users.

Necessarily, the first step in the analysis was a thorough study of the KC-135 boom system. All major components and some minor components were listed, and then the part numbers and the national stock numbers (NSNs) were identified. In order to complete the identification of the components, and to later gather cost information on the selected components, it was necessary to construct a work unit code (WUC) and NSN cross reference. This cross reference was necessary because all base level maintenance data was reported by WUC while at the depot, all parts and costs were managed by NSN. Next, available Air Force maintenance data collection systems and output products were evaluated as possible sources of values for the variables used in the model. The Increase Reliability of Operational Systems (IROS), an Air Force logistics support cost system, and its associated data products were used to identify those WUCs that contributed significantly to the cost of the KC-135 boom

system. Those FLUs that were identical on both systems were not considered because they would show no logistics support cost differences. Eventually, 15 assemblies and components were selected as FLUs for further analysis. A detailed explanation of this process can be found in Chapter III.

In only a few cases was it possible to extract data, from existing data products, that fit the exact definition of the model variables. In some cases, it was not possible to find data for the model variables, so some of the variables and equations were changed to allow available data to be substituted. Many changes in direction occurred as new data sources were found; and other, potential sources did not prove out.

In comparison to the KC-135 boom analysis, the analysis of the AARB was based on relatively little data; only the technical reports on the preliminary AARB design were available. After a thorough study of these reports, tentative AARB FLUs were identified. The identification of an assembly or component as a FLU was based on either of the following two criteria: (1) AARB components were identified, which were functional counterparts to KC-135 components, but incorporated different designs, or (2) AARB components were identified, which had no corresponding part in the KC-135 boom system, but seemed likely to add significantly to the logistics support cost. The fly-by-wire control system was the best example of a FLU that met the second criteria.

ATCA SPO logistics and engineering personnel estimated the values for the AARB FLU variables. These values were entered into the Boom Model and the resulting logistics support cost figure of merit was $33.35 million for ten years, in constant 1976 dollars. For comparison, the KC-135 boom figure of merit was $13.33 million. A detailed comparative analysis of the logistics support cost figures of merit for both boom systems can be found in Chapter IV.

Because of the uncertainty that existed in the initial estimates of the values for the AARB variables, sensitivity analyses were conducted on selected AARB variables to determine the effects of errors in the values of the variables and to identify those areas where management attention would yield the greatest logistics support cost payoff. A detailed discussion of the AARB sensitivity analyses can be found in Chapter V.

Conclusions

There are several conclusions that can be drawn from this research effort. Of obvious interest to those involved with the AARB development are those conclusions that relate to the logistics support cost figures of merit for the two boom systems and the results of the sensitivity analyses for the selected AARB components. Other conclusions relate to the LSC Model.

Logistics support cost conclusions. Two of the objectives of this research effort were to estimate logistics support cost figures of merit for the existing KC-135 boom

and Douglas Aircraft Company's proposed AARB. The KC-135 boom logistics support cost figure of merit was $13.33 million and the AARB logistics support cost figure of merit was $33.35 million. Therefore, the significant result was the $20.02 million higher cost to support the AARB.

Although it was not possible to estimate the size of the difference between the two results until the calculations had been completed, such a result should have been expected for several reasons. First, some of the costs of the KC-135 boom system are sunk costs, that is, costs which have already been incurred for the existing system, but would have to be considered if a new system were procured. In addition, the AARB represents increased capabilities, some of which introduce technical difficulties. The independent disconnect system greatly complicates the achievement of the desired higher fuel flow rates because part of the mechanism is imbedded in the wall of the nozzle. The automatic load alleviation system, through continuous trimming of the control surfaces, will add significantly to the safety and efficiency of aerial refueling; however, it is a feature of the expensive new electronic flight control system. A case will be made by some that improved technology of the newer system will result in substantial increases in reliability and ease of maintenance. However, such plans do not in every instance produce the expected results. Because of the risk associated with the unproved AARB design, most of the variables were estimated on the conservative side.

The major portion of the AARB logistics support cost estimate is concentrated in three FLUs. The fly-by-wire system components have the highest contribution at $7.26 million. This represents 22 percent of the total LSC figure of $33.35 million. The next highest cost FLU is the advanced nozzle which, including the independent disconnect, accounts for $5.79 million, or 17 percent of the total. The sensor package is third, at $2.31 million, which is 7 percent of the total LSC figure of merit. This, in a sense, further emphasizes the high costs which may be expected for the advanced capabilities of the fly-by-wire system since the sensor package can in reality be considered a part of this system. The magnitude of the cost of this system will be determined in the final analysis by the field MTBFs and the unit costs of the fly-by-wire components.

<u>LSC Model considerations</u>. There are two conclusions that relate to the LSC Model. They affect both the usefulness of the LSC Model and its ability to estimate the logistics support cost figures of merit between alternatives.

1. There are many logistics support costs not accounted for by the LSC Model. Some of these are omitted because they are not design sensitive. This includes such things as overhead costs of the support organizations. Other costs are omitted because they are not predictable. Such costs include the costs of modifications during the lifetime of the system. Still other costs are omitted because they are the same for both alternatives, or are associated with

FLUs which, considered by themselves, do not meet the minimum cost threshold for inclusion in the analysis. The omission of many costs makes the magnitude of the LSC figures questionable. The difference between the figures is the focus of the study, not the size of the figures; however, it is difficult to conceptually divorce the size of the estimates from the differences between them. A $5 million difference has a greater impact when considering a $10 million dollar system than when considering a $50 million system. It is vital that the limitations of the estimates and the omitted costs be fully explained to decision makers when providing them with the results of LSC Model analyses.

2. Very little has been written on the use of the LSC Model for analyzing existing systems. The researchers feel that the major contribution of this work has been the methodology used in obtaining values for the variables and the model changes which were developed to simplify the model, making it responsive to the data sources available for the system analyzed.

<u>Recommendations</u>

The following three recommendations are offered to assist future AFLC LSC Model users.

1. It is recommended that users of the AFLC LSC Model--and other models as well--write and publish the methodology they use in their analyses. To the best of the researchers' knowledge, this research report is the first to describe a methodology for obtaining data for the LSC Model

variables as they relate to an existing system. Although no two analyses are exactly alike, it is helpful to have the guidance provided by previous experience.

2. Some of the LSC Model equations should be simplified. For example, the writers simplified equation C_3 considerably by combining several terms so that available data sources could be used. Three variables were dropped from this equation with no apparent loss of discriminating capability. Other simplifications were made in equations C_2, C_5, C_6, and C_7. The writers suggest that some of these changes could be generalized to the analyses of other weapon systems. The result would be to increase the usefulness and broaden understanding of the model.

3. The LSC Model should be used with caution to compare systems that are in different phases of the system life cycle. In this research effort, the model had to be tailored in such a way that the sunk costs associated with the existing KC-135 boom system were eliminated. When new systems incorporate sizeable performance increases, the costs of those improvements usually can be expected to exceed the costs of the systems they are designed to replace. The exceptions to this will represent real support breakthroughs.

The following recommendation differs from the above in that it does not apply to the general use of the model, but arises from the results of this analysis and applies to the AARB system development.

The analysis showed that among all of the FLU parameters, MTBF is definitely the major support cost driver. Also, among the AARB FLUs, the fly-by-wire system is a potentially overpowering cost consumer. This would seem to highlight an area where engineering, logistics, and management attention could have major impact on future logistics support costs of the AARB system.

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APPENDIX A

Boom Model Variable Descriptions

This appendix describes in detail the variables used in the Boom Model. For each weapon system, system and FLU variable it gives a description, a data source code, the current value (for government-furnished standard variables only), and the dimensional units. The data source codes used are (a) R = estimated by the researchers for the KC-135 boom analysis or provided by the ATCA SPO for the AARB analysis, and (b) S = government-furnished standard value.

Weapon System Variables

1. EBO -- Standard established for expected backorders--the average number of supply backorders for weapon system components at base level at any point in time. (R, no dimensions)

2. IMC -- Initial management cost to introduce a new line item of supply--new NSN--into the Air Force inventory. (S = $46.60/item)

3. M -- Number of base locations that provide intermediate (base shop) maintenance and maintain a supply of parts for the weapon system. (R, base)

4. MRF -- Average number of man-hours per failure to complete off-equipment (base shop) maintenance records. (S = .24 hours/failure)

5. MRO -- Average number of man-hours per failure to complete on-equipment (flightline) maintenance records. (S = .08 hours/failure)

6. NSYS -- Number of systems within the weapon system. (R, no dimensions)

7. OS -- Fraction of total weapon system force deployed overseas. (R, no dimensions)

8. OSTCON -- Average order and shipping time within the continental United States. (S = .36 months)

9. OSTOS -- Average order and shipping time to overseas locations. (S = .53 months)

10. PFFH -- Peak force flying hours--the expected maximum number of hours to be flown by the total force during any one month. (R, hours/month)

11. PIUP -- Program inventory usage period--the number of years for which the logistics support costs are desired. (E, years)

12. PSC -- Average packing and shipping charge to locations within the continental United States. (S = $0.59/pound)

13. PSO -- Average packing and shipping charge to overseas locations. (S = $1.22/pound)

14. RMC -- Recurring management cost to maintain a line item of supply in the wholesale Air Force inventory system. (S = $104.20/item-year)

15. SA -- Annual base supply management cost to stock a line item of supply. (S = $36.59/item-year-base)

16. SR -- Average number of man-hours per failure to complete supply transaction records. (.25 hours/failure)

17. TD -- Average cost per original page for technical documentation--cost of an original contractor developed reproducible page, and not the cost of subsequent reproduction. (S = $220.00/page)

18. TFFH -- Total force flying hours--the expected number of flying hours for the total force over the program inventory usage period. (R, hours)

19. TR -- Average number of man-hours per failure to complete transportation transaction forms. (S = .16 hours/failure)

20. TRB -- Annual base personnel turnover rate. (S = .33/year)

System Variables

1. BLR -- Base labor rate. (S = $13.03/hour)

2. BMR -- Base consumable consumption rate--includes minor items of supply (nuts, washers, wire, rags, cleaning fluid, etc.) that are consumed while repairing FLUs. (S = $3.19/hour)

3. FB -- Total cost of new base facilities (including utilities) that must be constructed for operation and support of the system. (R, $/base)

4. FD -- Total cost of new depot facilities (including utilities) that must be constructed for support of the system. (R, $)

5. H -- Number of pages organizational, intermediate, and depot level technical orders and special repair instructions required to maintain the system. (R, pages)

6. KTYP -- A number indicating the boom system being evaluated. The number "135" indicates the KC-135 boom system and the number "1" indicates the AARB. It is a dummy variable that is used in determining the appropriate cost calculations. (R, no dimensions)

7. MENA -- Average number of avionics specialists that must be trained to support the AARB fly-by-wire system. (R, men)

8. MENB -- Average number of aerial refueling specialists that must be trained to support the boom system. (R, men)

9. N -- Number of different FLUs in the system. (R, no dimensions)

10. SECOST -- Total cost of new support equipment required to maintain the system--including flightline, base shop, depot, computer software for automatic test equipment, and interconnecting hardware for existing automatic test equipment. (R, $)

11. SHQ -- Average quarterly number of man-hours spent for scheduled on-equipment maintenance activities on the system. (R, hours/quarter)

12. SYSNOUN -- Name of system--up to 60 alphanumeric characters. (R, no dimensions)

13. TCA -- Average cost to train an avionics specialist to support the AARB fly-by-wire system--including technical school, on-the-job training to "5 level," and Field Training Detachment classes. (R, $/man)

14. TCB -- Average cost to train an aerial refueling system specialist--including technical school, on-the-job training to "5 level," and Field Training Detachment classes. (R, $/man)

15. TE -- Total cost of all system peculiar training equipment. (R, $)

16. XSYS -- System identification. The assigned five-digit alphanumeric WUC of the system.

FLU Variables

1. BMC -- Average cost per FLU failure for the labor associated with repairing lower level assemblies and components at base level, expressed as a fraction of the FLU unit cost (UC). (R, $/failure)

2. BMH -- Average number of man-hours to perform intermediate level (base shop) maintenance on the removed FLU--including troubleshooting, repairing, and testing. (R, hours/failure)

3. BRCT -- Average base repair cycle time. The average time it takes to repair the FLU in the base shops and return it to the supply system. (S = .13 months)

4. COND -- Fraction of removed FLUs that are expected to be condemned at base level. (R, no dimension)

5. DMX -- Average cost to repair the FLU at depot. This is a negotiated cost that includes labor, materials, lower level assemblies and components, overhead, training, and condemnations. (R, $/failure)

6. DRCT -- Average depot repair cycle time. The average time from removal of the failed FLU, that is coded as NRTS, repaired at the depot, and then returned to the depot serviceable stock. (S = 1.84 months for a depot repaired item and 2.25 months for an item that the depot contracts)

7. FLUNOUN -- Name of the FLU--up to 60 alphanumeric characters. (R, no dimensions)

8. IMH -- Average number of man-hours to perform corrective maintenance on the FLU while it is on the weapon system--including accessing, troubleshooting, repairing, and testing. (R, hours/failure)

9. K -- Number of line items of peculiar shop support equipment needed to repair the FLU. (R, always zero for these analyses)

10. MTBF -- Mean flying time between failures of the FLU, (R, hours/failure)

11. NRTS -- Fraction of removed FLUs that are expected to be returned to the depot for repair--not reparable this station. (R, no dimensions)

12. PA -- Number of new "P" coded reparable assemblies and consumable components within the FLU. (R, items)

13. QPA -- Quantity per application--the number of identical FLUs in the parent system. (R, no dimensions)

14. RIP -- Fraction of FLU failures which are repaired in-place. (R, no dimensions)

15. RMH -- Average number of man-hours to remove and replace the failed FLU--including accessing, troubleshooting, and testing. (R, hours/failure)

16. RTS -- Fraction of removed FLUs that are expected to be repaired at base level. (R, no dimensions)

17. SP -- Number of standard, already stock numbered, parts within the FLU which will be carried as a base supply item for the first time at bases that support the system. (R, items)

18. UC -- Expected acquisition cost of the FLU at the time of the analyses. (R, $)

19. UF -- Ratio of the number of operating hours to the number of flying hours for the FLU--use factor. (E, always equal to one for these analyses)

20. W -- FLU unit weight. (R, pounds)

21. XFLU -- FLU identification. The assigned five-digit alphanumeric WUC for the FLU. (R, no dimensions)

The descriptions of some of the above variables are identical to those given in the Model Handbook (51:2-1 to 2-7). Some have been changed either for clarity or a new meaning, and some have been added.

APPENDIX B

Table XVI
Boom Model Variables, Data Input Format, and Data Files[1]

LEVEL	VARIABLES
Weapon System	LN[2] TFFH PFFH PIUP M OS EBO NSYS
	LN OSTCON OSTOS IMC RMC PSC PSO TRB
	LN TD SA MRF MRO SR TR
System (4 lines for each system)	LN XSYS SYSNOUN
	LN SHQ SECOST N
	LN FB FD H TCB TCA MENB MENA KTYP TE
	LN BLR BMR
FLU (4 lines for each FLU)	LN XFLU FLUNOUN
	LN QPA UC MTBF UF RIP RTS NRTS COND BMC DMX
	LN IMH RMH BMH W PA SP K
	LN BRCT DRCT

[1] This table shows the input sequence for the values of the variables used in the Boom Model. The computer program is written to accept data in this format. Any other format will result in either a computation error or an erroneous answer.

[2] LN is the line number in the data file.

[3] The last three pages of this appendix show the KC-135 boom and AARB data files.

KC-135 BOOM SYSTEM DATA FILE

```
010 2400000 60000 10 36 .071 .1 1
20 .36 .53 0 104.20 .59 1.22 .33
30 220.00 36.59 .24 .08 .25 .16
40 467XX "KC-135A AERIAL REFUELING BOOM SYSTEM"
050 8200 0 15
60 0 0 0 6931 17146 0 5 135 0
70 13.03 3.19
80 4676B "BOOM FORK ASSEMBLY"
90 1 1102.56 8836 1 .92 .58 .40 .02 .021 794.84
100 1.4 6.7 2.6 8 0 0 0
110 .13 2.25
120 46766 "RUDDEVATORS"
130 2 3804.31 2754 1 .87 .50 .58 .00 .009 1509.51
140 1.3 2.5 5.5 151 0 0 0
150 .13 2.25
160 46794 "RUDDEVATOR BOOST UNIT"
170 2 3359.65 1844 1 .87 .74 .26 .00 .009 716.25
180 1.9 6.0 3.9 20 0 0 0
190 .13 2.25
200 46768 "RUDDEVATOR QUADRANT ASSEMBLY"
210 4 364.56 4158 1 .82 .00 .00 1.00 .108 0
220 2.7 8.5 2.5 2.25 0 0 0
230 .13 0
240 4676A "RUDDEVATOR LOCK ROLLER ASSEMBLY"
250 1 3.53 459 1 .45 .00 .00 1.00 .00 0
260 0.7 1.1 1.4 .25 0 0 0
270 .13 0
280 51921 "TRANSMITTER"
290 3 121.60 2272 1 .72 .00 .00 1.00 .00 0
300 3.5 4.0 1.1 2 0 0 0
310 .13 0
320 46857 "ELEVATION CONTROL UNIT"
330 1 2022.14 1178 1 .90 .29 .59 .12 .025 368.67
340 3.4 4.9 3.6 8 0 0 0
350 .13 1.84
360 4685A "AZIMUTH CONTROL UNIT"
370 1 239.15 1537 1 .92 .44 .41 .15 .073 155
380 1.1 4.8 3.7 3 0 0 0
390 .13 1.84
400 46851 "SIGNAL COIL AMPLIFIER"
410 1 175.00 339 1 .92 .00 .00 1.00 .180 0
420 2.3 3.0 2.4 .75 0 0 0
430 .13 0
440 46773 "SURGE BOOT"
450 2 496.00 5891 1 .88 .00 .00 1.00 .00 0
460 1.6 6.7 6.3 31 0 0 0
470 .13 0
480 4676H "GLAND SEAL "
490 1 41.60 2525 1 .92 .00 .00 1.00 .00 0
500 2.9 14.2 4.3 1 0 0 0
510 .13 0
520 46771 "NOZZLE"
530 1 7273.60 202 1 .83 .79 .21 .00 .004 499.20
540 1.5 3.5 6.0 31.5 0 0 0
550 .13 2.25
560 46772 "TAILCONE"
570 1 12035.00 862 1 .83 .35 .63 .02 .004 4782.97
```

```
580 1.7 3.7 8.2 50 0 0 0
590 .13 2.25
600 46778 "EXTENSION DRIVE UNIT"
610 1 4736.00 1657 1 .92 .44 .56 .00 .005 6314.67
620 1.6 3.6 4.0 49 0 0 0
630 .13 1.84
640 46854 "TELESCOPE CONTROL UNIT"
650 1 8450.00 7573 1 .89 .14 .86 .01 .007 375.55
660 4.2 7.4 2.0 9 0 0 0
670 .13 2.25
```

AARB SYSTEM DATA FILE

```
010 2400000 60000 10 36 .071 .1 1
020 .36 .53 46.60 104.20 .59 1.22 .33
030 220.00 36.59 .24 .08 .25 .16
040 467XX "ADVANCED AERIAL REFUELING BOOM SYSTEM"
050 8200 2160000.00 12
060 0 0 2127 6931.00 17146.00 1 5 1 0
070 13.03 3.19
080 4676B "ROLLING BOOM PIVOT ASSEMBLY"
090 1 5000.00 10000 1 .92 .58 .40 .02 .021 1000.00
100 1.4 6.7 2.6 20 4 0 0
110 .13 2.25
120 46766 "FLIGHT CONTROL SURFACES"
130 5 5000.00 3000 1 .87 .5 .5 0 .009 1500.00
140 1.3 2.5 5.5 30 0 0 0
150 .13 2.25
160 46794 "SERVO CONTROLS AND ACTUATORS"
170 6 5000.00 1800 1 .87 .5 .5 0 .009 1000.00
180 1.9 6.0 3.9 10 1 0 0
190 .13 2.25
200 51921 "SENSOR PACKAGE"
210 16 350.00 2500 1 .72 0 0 1 0 0
220 3.5 4.0 1.1 2 0 0 0
230 .13 0
240 46851 "SIGNAL COIL AMPLIFIER"
250 1 175.00 1000 1 .92 0 0 1 .180 0
260 2.3 3.0 2.4 .75 1 0 0
270 .13 0
280 46773 "SURGE BOOT"
290 1 1000.00 10000 1 .88 0 0 1 0 0
300 1.6 3.0 3.0 100 0 0 0
310 .13 0
320 4676H "SLIDING GLAND SEAL"
330 1 100.00 10000 1 .92 0 0 1 0 0
340 2.9 14.2 4.3 1 0 0 0
350 .13 0
360 46771 "NOZZLE"
370 1 15000.00 200 1 .5 .79 .2 .01 .005 750.00
380 3.0 5.0 8.0 55 6 0 0
390 .13 2.25
400 46772 "TAILCONE"
410 1 15000.00 1700 1 .83 .35 .63 .02 .004 5000.00
420 1.0 3.0 8.2 40 0 0 0
430 .13 2.25
440 46778 "EXTENSION DRIVE ASSEMBLY"
450 1 5700.00 2400 1 .92 .44 .56 0 .005 6300.00
460 1.6 3.6 4.0 60 2 0 0
470 .13 1.84
480 46765 "EXTENSION AND RETRACTION SHOCK ABSORBERS"
490 2 5000.00 10000 1 .57 .5 .5 0 .004 550.00
500 2.1 3.3 4.1 20 1 0 0
510 .13 2.25
520 46755 "FLY-BY-WIRE CONTROL SYSTEM"
530 1 25000.00 1000 1 .1 .185 .8 .015 .005 1500.00
540 1.0 1.0 3.0 100 4 0 0
550 .13 2.25
```

APPENDIX C

Boom Model Computer Program

This appendix contains the Boom Model computer program. The program is an interactive, time-sharing program. It is adapted from the LSC Model computer program.

The LSC model, as explained in the LSC Model User's Handbook, is programmed in FORTRAN for use with the AFLC Computational Resources for Engineering and Simulation, Training and Education (CREATE) System (51:6). The model has been programmed for both time sharing and batch modes of operation.

```
****************************************
*****************  BOOM  *************
****************************************
      DIMENSION FLUMAT(100,18),SEMAT(100,9),SYSMAT(30,13),SECUM(50,5)
      DIMENSION SORTFLU(100,18),EQTOT(10)
      CHARACTER XSYS*5(30),XFLU*5(100,2),XSE*20(100),SORTXFLU*5(100,2)
      CHARACTER SYSNOUN*60(30),FLUNOUN*60(100),SEFLU*5(100,2),CANS*5
      CHARACTER XSECUM*20(50),DATE*8
      DATA SYSMAT,FLUMAT,EQTOT/2200*0./
       REAL H,IMC,IMH,M,MRO,MRF,MTBF,NRTS
       TOTLSC=0.
**************************************************
*********** READ WEAPON SYSTEM VARIABLES ***********
**************************************************
       READ(10,2) LN, TFFH,PFFH,PIUP,M,DS,EBO,NSYS
       READ(10,2) LN, OSTCON,OSTOS,IMC,RMC,PSC,PSO,TRB
       READ(10,2) LN, TD,SA,MRF,MRO,SR,TR
     2 FORMAT(V)
       IF(NSYS.LE.30) GO TO 30
       PRINT 3
     3 FORMAT("SYSMAT ARRAY MUST BE REDIMENSIONED")
       STOP
    30 INEXT=1
       JNEXT=1
**************************************************
************* READ SYSTEM VARIABLES **********
**************************************************
       DO 1000 IS=1,NSYS
       READ(10,2) LN,XSYS(IS),SYSNOUN(IS)
       READ(10,2) LN,SHQ,SECOST,N
       READ(10,2) LN,FB,FD,H,TCB,TCA,MENA,MENB,KTYP,TE
       READ(10,2) LN,BLR,BMR
       SYSMAT(IS,2)=SHQ*4*PIUP*BLR
       SYSMAT(IS,5)=SECOST
       IF(KTYP.EQ.135) GO TO 31
       C6X=(1.+(PIUP-1.)*TRB)*(TCB*MENB+TCA*MENA)*M+TE
       GO TO 33
    31 C6X=PIUP*TRB*TCB*MENB*M+TE
    33 SYSMAT(IS,6)=C6X
       SYSMAT(IS,7)=TD*H
       SYSMAT(IS,8)=M*FB+FD
       GO TO 34
    34 IF(N.EQ.0) GO TO 1000
****************************************
********** READ FLU VARIABLES **********
****************************************
       IMAX=INEXT+N-1
       IF(IMAX.LE.100) GO TO 38
       PRINT 37
    37 FORMAT("FLUMAT ARRAY MUST BE REDIMENSIONED")
       STOP
    38 DO 999 I=INEXT,IMAX
       READ(10,2) LN,XFLU(I,1),FLUNOUN(I)
       READ(10,2) LN,OPA,UC,MTBF,UF,RIP,RTS,NRTS,COND,BMC,DMX
```

```
      READ(10,2) LN,IMH,RMH,BMH,W,PA,SP,K
      READ(10,2) LN,BRCT,DRCT
      XFLU(I,2)=XSYS(IS)
      PKGEN=PFFH*OPA*UF/MTBF
      FLUMAT(I,9)=PKGEN
      PKOEGEN=PKGEN*(1.-RIP)
      FLUMAT(I,10)=PKOEGEN
      TOTGEN=IFFH*OPA*UF/MTBF
      FLUMAT(I,11)=TOTGEN
      TOTOEGEN=TOTGEN*(1.-RIP)
      FLUMAT(I,12)=TOTOEGEN
      DMDMEAN=PKOEGEN*(BRCT*RTS+NRTS*((1.-OS)*OSTCON+OS*OSTOS))/M
      FLUMAT(I,14)=DMDMEAN

*****************************************************
********** COMPUTE BASE FLU SPARES STOCK LEVEL **********
*****************************************************
      XBO=DMDMEAN
      PROBX=EXP(-DMDMEAN)
      STK=0.
      SUM=0.
   41 IF(XBO.LE.EBO) GO TO 45
      SUM=SUM+PROBX
      XBO=XBO+SUM-1.
      STK=STK+1.
      PROBX=PROBX*DMDMEAN/STK
      GO TO 41
   45 CONTINUE
      DPIPE=IFIX(PKOEGEN*NRTS*DRCT + 0.99999999)
      TOTCOND=IFIX(TOTOEGEN*COND + 0.99999999)
      FLUMAT(I,15)=XBO
      FLUMAT(I,16)=STK
      FLUMAT(I,17)=DPIPE
      FLUMAT(I,18)=TOTCOND
      IF(KTYP.EQ.135) GO TO 32
      FLUMAT(I,1)=UC*(STK*M+DPIPE+TOTCOND)
      GO TO 35
   32 FLUMAT(I,1)=UC*TOTCOND
   35 FLUMAT(I,2)=TOTGEN*(RIP*IMH+(1.-RIP)*RMH)*BLR
      FLUMAT(I,3)=TOTOEGEN*(RTS*(BMH*(BLR+BMR)+BMC*UC)+
     $NRTS*DMX+(2.*NRTS*COND)*((1.-OS)*PSC+
     &OS*PSO)*1.35*W)
       IF(RTS.NE.0.) GO TO 46
       FLUMAT(I,4)=(IMC+PIUP*RMC)*(1.+PA)+M*SA*PIUP
       GO TO 47
   46 FLUMAT(I,4)=(IMC+PIUP*RMC)*(1.+PA)+M*SA*PIUP*(1.+PA+SP)
   47 FLUMAT(I,6)=0
      FLUMAT(I,7)=TOTGEN*(MRO+(1.-RIP)*(MRF+SR+TR))*BLR
       IF (K.EQ.0) GO TO 999
  999 CONTINUE
       INEXT=INEXT+N
 1000 CONTINUE
       CALL DETACH(10,ISTAT, )

*************************************
********** COMPUTE FLU COST ***********
*************************************
   91 DO 92 IB=1,I
       DO 92 IC=1,7
       FLUMAT(IB,8)=FLUMAT(IB,8)+FLUMAT(IB,IC)
   92 CONTINUE

*****************************************
********** COMPUTE SYSTEM COST **********
*****************************************
       DO 96 IK=1,NSYS
```

```
      DO 93 JO=1,10
      SYSMAT(IK,11)=SYSMAT(IK,11)+SYSMAT(IK,JO)
   93 CONTINUE
      DO 95 IL=1,I
      IF(XFLU(IL,2).NE.XSYS(IK)) GO TO 95
      DO 94 IM=1,7
      SYSMAT(IK,IM)=SYSMAT(IK,IM)+FLUMAT(IL,IM)
   94 CONTINUE
   95 CONTINUE
   96 CONTINUE
      DO 97 JN=1,NSYS
      DO 97 JP=1,10
      SYSMAT(JN,12)=SYSMAT(JN,12)+SYSMAT(JN,JP)
   97 CONTINUE

*****************************************
*********** COMPUTE WEAPON SYSTEM COST **********
*****************************************
      DO 98 IN=1,NSYS
      TOTLSC=TOTLSC+SYSMAT(IN,12)
   98 CONTINUE
      TOTLSC=TOTLSC+EQTOT(5)

*********************************
*********** PRINT OUTPUT **********
*********************************
      CALL YADATE(DATE)
      CALL YTIME(ITIME)
      PRINT 112,DATE,ITIME/100000*100000
  112 FORMAT(//"RUN OF ",A8," -- ",I4," HOURS")
      IF(TOTLSC.LT.10**6) GO TO 121
      IF(TOTLSC.LT.10**9) GO TO 117
      PRINT 115,TOTLSC/10**9
  115 FORMAT(//"TOTAL LSC = $",F7.2," BILLION.")
      GO TO 140
  117 PRINT 119,TOTLSC/10**6
  119 FORMAT(//"TOTAL LSC = $",F7.2," MILLION.")
      GO TO 140
  121 PRINT 123,TOTLSC
  123 FORMAT(//"TOTAL LSC = $",F7.0)
  140 DO 132 KC=1,100
      DO 130 KD=1,18
  130 SORTFLU(KC,KD)=FLUMAT(KC,KD)
      DO 131 KE=1,2
  131 SORTXFLU(KC,KE)=XFLU(KC,KE)
  132 CONTINUE
      CALL SORT(SYSMAT,30,13,12,XSYS,1)
      CALL SORT(SORTFLU,100,18,8,SORTXFLU,2)
      PRINT 142
  142 FORMAT(/"DO YOU WANT AN EXPLANATION OF YOUR AVAILABLE ",
&     "OPTIONS")
      READ 2003,CANS
      IF(CANS.NE."Y") GO TO 150
      PRINT 145
  145 FORMAT(/"OPTION 1 - TOTAL LSC BROKEN OUT BY EQUATION"/
&     "OPTION 2 - ALL SYSTEMS RANKED ON COST"/
&     "OPTION 3 - COST BREAKOUT BY EQUATION FOR A PARTICULAR SYSTEM"/
&     "OPTION 4 - COST RANKING OF FLUS FOR A PARTICULAR SYSTEM"/
&     "OPTION 5 - COST BREAKOUT BY EQUATION FOR A PARTICULAR FLU"/
&     "OPTION 6 - DETAILED SUPPORT EQUIPMENT ANALYSIS"/
&     "OPTION 7 - DETAILED SPARES ANALYSIS"/
&     "OPTION 8 - MAINTENANCE GENERATIONS ANALYSIS"/
&     "OPTION 9 - FLU WORK UNIT CODE/NOUN CROSS-REFERENCE"/
&     "OPTION 10 - STOP PROGRAM")
  150 PRINT 151
  151 FORMAT(/"WHICH OPTION")
```

```
1900  155 READ:IANS
1910      IF(IANS.GT.10) GO TO 140
1920      GO TO (200,250,300,350,400,450,500,550,600,650) .IANS
1930
1940*************************************
1950********** OUTPUT OPTION 1 ************
1960*************************************
1970  200 DO 210 MP=1,10
1980      DO 210 MR=1,NSYS
1990  210 EQTOT(MP)=EQTOT(MP)+SYSMAT(MR,MP)
2000      PRINT 335
2010      PRINT 345,(EQTOT(MS),MS=1,5)
2020      PRINT 340
2030      PRINT 345,(EQTOT(MS),MS=6,8)
2040      GO TO 150
2050
2060************************
2070**** OUTPUT OPTION 2 ****
2080************************
2090  250 PRINT 260
2100  260 FORMAT(10X,"SYSTEM",4X,"COST(IN MILLIONS)",4X,
2110&     "FRACTION OF TOTAL LSC")
2120      DO 280 IX=1,NSYS
2130      SYSMAT(IX,13)=SYSMAT(IX,12)/TOTLSC
2140      SYSCOST=SYSMAT(IX,12)/10**6
2150      PRINT 270,XSYS(IX),SYSCOST,SYSMAT(IX,13)
2160  270 FORMAT(11X,A5,F18.2,F19.2)
2170  280 CONTINUE
2180      GO TO 150
2190
2200************************
2210**** OUTPUT OPTION 3 ****
2220************************
2230  300 PRINT 2006
2240  310 READ 2004,CANS
2250      DO 320 IE=1,NSYS
2260      IF(XSYS(IE).EQ.CANS) GO TO 330
2270  320 CONTINUE
2280      PRINT 2002
2290      GO TO 310
2300  330 PRINT  335
2310  335 FORMAT(/"EQUATION",10X,"#1",10X,"#2",10X,"#3",10X,"#4",10X,"#5")
2320      PRINT 345,(SYSMAT(IE,IG),IG=1,5)
2330      PRINT 340
2340  340 FORMAT("EQUATION",10X,"#6",10X,"#7",10X,"#8")
2350      PRINT 345,(SYSMAT(IE,ID),ID=6,8)
2360  345 FORMAT(12X,5F12.0//)
2370      GO TO 150
2380
2390************************
2400**** OUTPUT OPTION 4 ****
2410************************
2420  350 PRINT 2006
2430  355 READ 2004,CANS
2440      DO 360 IP=1,NSYS
2450      IF(XSYS(IP).NE.CANS) GO TO 360
2460      GO TO 365
2470  360 CONTINUE
2480      PRINT 2002
2490      GO TO 355
2500  365 PRINT:"HOW MANY FLUS TO BE INCLUDED IN RANKING"
2510      READ:IANS
2520      PRINT 370
2530  370 FORMAT(49X,"FRACTION OF"/16X,"FLU",12X,"COST",14X,
2540&     "SYSTEM COST"//)
2550      PCIQ=0.
```

```
      IR=0
      DO 380 IY=1,I
      IF(SORTXFLU(IY,2).NE.CANS) GO TO 380
      IR=IR+1
      PCT=SORTFLU(IY,8)/SYSMAT(IP,12)
      PCTG=PCTG+PCT
      PRINT 375,IR,SORTXFLU(IY,1),SORTFLU(IY,8),PCT
 375  FORMAT(I9,A11,F18.0,F18.2)
      IF(IR.EQ.IANS) GO TO 385
 380  CONTINUE
      IF(IR.EQ.IANS) GO TO 385
      PRINT:"THESE ARE ALL THE FLUS IN THIS SYSTEM."
      IANS=IR
 385  IPCTG=PCTG*100
      PRINT 390,IANS,IPCTG
 390  FORMAT(/"CONTRIBUTION OF TOP",I3," FLUS =",I3,
&     " PER CENT OF TOTAL SYSTEM COST.")
      PRINT 395,SYSMAT(IP,12)/10**6
 395  FORMAT("SYSTEM COST = $",F8.2," MILLION.")
      GO TO 150

*************************
**** OUTPUT OPTION 5 ****
*************************
 400  PRINT 2008
 405  READ 2004,CANS
      DO 410 IU=1,I
      IF(SORTXFLU(IU,1).NE.CANS) GO TO 410
      GO TO 415
 410  CONTINUE
      PRINT 2002
      GO TO 405
 415  PRINT 420
 420  FORMAT(/"EQUATION",7X,"#1",12X,"#2",12X,"#3",12X,"#4")
      PRINT 425,(SORTFLU(IU,IV),IV=1,4)
 425  FORMAT(7X,4F14.0//)
      PRINT 430
 430  FORMAT("EQUATION",7X,"#5",12X,"#6",12X,"#7")
      PRINT 435,(SORTFLU(IU,JL),JL=5,7)
 435  FORMAT(7X,3F14.0//)
      GO TO 150

*************************
**** OUTPUT OPTION 6 ****
*************************
 450  GO TO 150

******************************************
********** OUTPUT OPTION 7 **************
******************************************
 500  PRINT 510
 510  FORMAT(28X,
&     "FLUS"//4X,"WUC",7X,"DMDMEAN",8X,"XBO",9X,"STK",7X,"DPIPE",
&     6X,"TOTCOND"//)
      DO 530 MU=1,I
      PRINT 520,XFLU(MU,1),(FLUMAT(MU,MX),MX=14,18)
 520  FORMAT(3X,A5,2F12.2,3F12.0)
 530  CONTINUE
      GO TO 150

*********************************
********* OUTPUT OPTION 8 *******
*********************************
 550  PRINT 560
 560  FORMAT(31X,"PEAK",25X,"TOTAL"/20X,"PEAK",5X,"OFF-EQUIP",10X,
&     "TOTAL",5X,"OFF-EQUIP"/7X,"WUC",10X,"GENS",7X,"GENS",14X,"GENS",
```

```
      8X,"GENS"//)
      DO 570 MV=1,I
      PRINT 565,XFLU(MV,1),(FLUMAT(MV,MY),MY=9,12)
  565 FORMAT(6X,A5,6X,F8.2,F11.2,F10.2,F12.2)
  570 CONTINUE
      GO TO 150

*****************************************
********* OUTPUT OPTION 9 **************
*****************************************
  600 PRINT 610
  610 FORMAT(/3X,"WUC",7X,"NOUN"//)
      DO 625 JZ=1,I
      PRINT 620,XFLU(JZ,1),FLUNOUN(JZ)
  620 FORMAT(2X,A5,3X,A60)
  625 CONTINUE
      GO TO 150
 2002 FORMAT("IMPROPER IDENTIFICATION--RETYPE")
 2003 FORMAT(A1)
 2004 FORMAT(A5)
 2006 FORMAT("SYSTEM IDENTIFICATION")
 2008 FORMAT("FLU IDENTIFICATION")
  650 STOP
      END

*****************************************************
********** SUBROUTINE TO SORT GIVEN MATRIX **********
*****************************************************
      SUBROUTINE SORT(XMAT,MAXROW,MAXCOL,NCOL,YMAT,ICOL)
      DIMENSION XMAT(MAXROW,MAXCOL)
      CHARACTER YMAT*5(MAXROW,ICOL),CTEMP*5
      IMAX=MAXROW-1
      DO 700 I=1,IMAX
      JFIRST=I+1
      DO 700 J=JFIRST,MAXROW
      IF(XMAT(I,NCOL).GE.XMAT(J,NCOL)) GO TO 700
      DO 690 K=1,MAXCOL
      TEMP=XMAT(I,K)
      XMAT(I,K)=XMAT(J,K)
      XMAT(J,K)=TEMP
  690 CONTINUE
      DO 695 L=1,ICOL
      CTEMP=YMAT(I,L)
      YMAT(I,L)=YMAT(J,L)
      YMAT(J,L)=CTEMP
  695 CONTINUE
  700 CONTINUE
      RETURN
      END
```

APPENDIX D

Table XVII
Values for KC-135/AARB FLU Variables

KC-135 FLU / AARB FLU	QPA	UC*	MTBF	UF	RIP	RTS	NRTS	COND	BMC	DMX*	IMH	RMH	BMH	W	PA	SP	K	BRCT	DRCT
Boom Fork Assy	1	1103	8836	1	.92	.58	.40	.02	.021	795	1.4	6.7	2.6	8	0	0	0	.13	2.25
Rolling Boom Pivot Assy	1	5000	10000	1	.92	.58	.40	.02	.021	1000	1.4	6.7	2.6	20	4	0	0	.13	2.25
Ruddevators	2	3804	2754	1	.87	.50	.50	0	.009	1510	1.3	2.5	5.5	151	0	0	0	.13	2.25
Flight Control Surfaces	5	5000	3000	1	.87	.50	.50	0	.009	1500	1.3	2.5	5.5	30	0	0	0	.13	2.25
Ruddevator Boost Units	2	3360	1844	1	.87	.74	.26	0	.009	716	1.9	6.0	3.9	20	0	0	0	.13	2.25
Servo Controls And Actuators	6	5000	1800	1	.87	.50	.50	0	.009	1000	1.9	6.0	3.9	10	1	0	0	.13	2.25
Boom Position Transmitters	3	122	2272	1	.72	0	0	1.00	0	0	3.5	4.0	1.1	2	0	0	0	.13	0
Sensor Package	16	350	2500	1	.72	0	0	1.00	0	0	3.5	4.0	1.1	2	0	0	0	.13	0
Azimuth Control Unit	1	239	1537	1	.92	.44	.41	.15	.073	155	1.1	4.8	3.7	3	0	0	0	.13	1.84
N/A																			
Elevation Control Unit	1	2022	1178	1	.90	.29	.59	.12	.025	369	3.4	4.9	3.6	8	0	0	0	.13	1.84
N/A																			

*Costs are rounded to nearest whole dollar.

Continued

Table XVII (Continued)
Values for KC-135/AARB FLU Variables

KC-135 FLU / AARB FLU	QPA	UC*	MTBF	UF	RIP	RTS	NRTS	COND	BMC	DMX*	IMH	RMH	BMH	W	PA	SP	K	BRCT	DRCT
Surge Boots	2	496	5891	1	.88	0	0	1.00	0	0	1.6	6.7	6.3	31	0	0	0	.13	0
Surge Boot	1	1000	10000	1	.88	0	0	1.00	0	0	1.6	3.0	3.0	100	0	0	0	.13	0
Sliding Gland Seal	1	42	2525	1	.92	0	0	1.00	0	0	2.9	14.2	4.3	1	0	0	0	.13	0
Sliding Gland Seal	1	100	10000	1	.92	0	0	1.00	0	0	2.9	14.2	4.3	1	0	0	0	.13	0
Nozzle	1	7274	202	1	.83	.79	.21	0	.004	499	1.5	3.5	6.0	31.5	0	0	0	.13	2.25
Nozzle	1	15000	200	1	.5	.79	.20	.01	.005	750	3.0	5.0	8.0	55	6	0	0	.13	2.25
Tailcone	1	12035	862	1	.83	.35	.63	.02	.004	4783	1.7	3.7	8.2	50	0	0	0	.13	2.25
Tailcone	1	15000	1700	1	.83	.35	.63	.02	.004	5000	1.0	3.0	8.2	40	0	0	0	.13	2.25
Extension Drive Unit	1	4736	1657	1	.92	.44	.56	0	.005	6315	1.6	3.6	4.0	49	0	0	0	.13	1.84
Extension Drive Unit	1	5700	2400	1	.92	.44	.56	0	.005	6300	1.6	3.6	4.0	60	2	0	0	.13	1.84
N/A																			
Ext/Ret Shock Absorbers	2	5000	10000	1	.57	.50	.50	0.	.004	550	2.1	3.3	4.1	20	1	0	0	.13	2.25

*Costs are rounded to nearest whole dollar.

Continued

Table XVII (Continued)
Values for KC-135/AARB FLU Variables

KC-135 FLU / AARB FLU	QPA	UC*	MTBF	UF	RIP	RTS	NRTS	COND	BMC	DMX*	IMH	RMH	BMH	W	PA	SP	K	BRCT	DRCT
Telescope Control Unit	1	8450	7573	1	.89	.14	.86	.01	.007	376	4.2	7.4	2.0	9	0	0	0	.13	2.25
N/A																			
N/A																			
Fly-By-Wire Control System	1	25000	1000	1	.10	.185	.80	.015	.005	1500	1.0	1.0	3.0	100	4	0	0	.13	2.25
Ruddevator Quadrant	4	365	4158	1	.82	0	0	1.00	.108	0	2.7	8.5	2.5	2.25	0	0	0	.13	0
N/A																			
Ruddevator Lock Roller Assy.	1	4	459	1	.45	0	0	1.00	0	0	.7	1.1	1.4	.25	0	0	0	.13	0
N/A																			
Signal Coil Amplifier	1	175	339	1	.92	0	0	1.00	.180	0	2.3	3.0	2.4	.75	0	0	0	.13	0
Signal Coil Amplifier	1	175	1000	1	.92	0	0	1.00	.180	0	2.3	3.0	2.4	.75	1	0	0	.13	0

*Costs are rounded to nearest whole dollar.

APPENDIX E

KC-135 Boom System

Logistics Support Cost Analysis

This appendix contains the computer output product for the KC-135 boom system logistics support cost analysis. It displays all nine output options. The analysis of this appendix appears in Chapter IV.

KC-135 LOGISTICS SUPPORT COST ANALYSIS

TOTAL LSC = $ 13.33 MILLION.

AVAILABLE OPTIONS

OPTION 1 - TOTAL LSC BROKEN OUT BY EQUATION
OPTION 2 - ALL SYSTEMS RANKED ON COST
OPTION 3 - COST BREAKOUT BY EQUATION FOR A PARTICULAR SYSTEM
OPTION 4 - COST RANKING OF FLUS FOR A PARTICULAR SYSTEM
OPTION 5 - COST BREAKOUT BY EQUATION FOR A PARTICULAR FLU
OPTION 6 - DETAILED SUPPORT EQUIPMENT ANALYSIS
OPTION 7 - DETAILED SPARES ANALYSIS
OPTION 8 - MAINTENANCE GENERATIONS ANALYSIS
OPTION 9 - FLU WORK UNIT CODE/NOUN CROSS-REFERENCE
OPTION 10 - STOP PROGRAM

OPTION 1

EQUATION	#1	#2	#3	#4	#5
	605826.	5542952.	2733089.	213216.	0.

EQUATION	#6	#7	#8
	4117014.	117878.	0.

OPTION 2

SYSTEM	COST(IN MILLIONS)	FRACTION OF TOTAL LSC
467XX	13.33	1.00

OPTION 3
SYSTEM 467XX

EQUATION	#1	#2	#3	#4	#5
	605826.	5542952.	2733089.	213216.	0.

EQUATION	#6	#7	#8
	4117014.	117878.	0.

OPTION 4
SYSTEM 467XX
15 FLUS IN RANKING

	FLU	COST	FRACTION OF SYSTEM COST
1	46772	1697684.	0.13
2	46771	764910.	0.06
3	46778	469634.	0.04
4	46851	343316.	0.03
5	46768	285232.	0.02
6	51921	284838.	0.02
7	46766	265331.	0.02
8	46857	215426.	0.02
9	46794	191761.	0.01
10	4676A	117470.	0.01
11	46773	90582.	0.01
12	4676H	66230.	0.00
13	4685A	62355.	0.00
14	46854	54258.	0.00
15	4676B	38094.	0.00

CONTRIBUTION OF TOP 15 FLUS = 37 PER CENT OF TOTAL SYSTEM COST.
SYSTEM COST = $ 13.33 MILLION.

OPTION 5
FLU 46772 - TAILCONE

EQUATION	#1	#2	#3	#4
	120350.	74008.	1482201.	14214.
EQUATION	#5	#6	#7	
	0.	0.	6911.	

OPTION 5
FLU 46771 - NOZZLE

EQUATION	#1	#2	#3	#4
	0.	284854.	436350.	14214.
EQUATION	#5	#6	#7	
	0.	0.	29492.	

OPTION 5
FLU 46778 - EXTENSION DRIVE UNIT

EQUATION	#1	#2	#3	#4
	0.	33216.	419713.	14214.
EQUATION	#5	#6	#7	
	0.	0.	2491.	

OPTION 5
FLU 46851 - SIGNAL COIL AMPLIFIER

EQUATION	#1	#2	#3	#4
	99225.	217336.	364.	14214.
EQUATION	#5	#6	#7	
	0.	0.	12177.	

OPTION 5
FLU 46766 - RUDDEVATORS

EQUATION	#1	#2	#3	#4
	0.	33066.	214315.	14214.
EQUATION	#5	#6	#7	
	0.	0.	3736.	

OPTION 5
FLU 46768 - RUDDEVATOR QUADRANT ASSEMBLY

EQUATION	#1	#2	#3	#4
	151657.	112633.	801.	14214.
EQUATION	#5	#6	#7	
	0.	0.	5926.	

OPTION 5
FLU 51921 - TRANSMITTERS

EQUATION	#1	#2	#3	#4
	107981.	150304.	1521.	14214.
EQUATION	#5	#6	#7	
	0.	0.	10819.	

OPTION 5
FLU 46857 - ELEVATION CONTROL UNIT

EQUATION	#1 50554.	#2 94241.	#3 52568.	#4 14214.
EQUATION	#5 0.	#6 0.	#7 3849.	

OPTION 5
FLU 46794 - RUDDEVATOR BOOST UNITS

EQUATION	#1 0.	#2 82521.	#3 89445.	#4 14214.
EQUATION	#5 0.	#6 0.	#7 5579.	

OPTION 5
FLU 4676A - RUDDEVATOR LOCK ROLLER ASSEMBLY

EQUATION	#1 10152.	#2 62688.	#3 616.	#4 14214.
EQUATION	#5 0.	#6 0.	#7 29807.	

OPTION 5
FLU 46773 - SURGE BOOTS

EQUATION	#1 48608.	#2 23485.	#3 2597.	#4 14214.
EQUATION	#5 0.	#6 0.	#7 1677.	

OPTION 5
FLU 4676H - GLAND SEAL

EQUATION	#1 3203.	#2 47112.	#3 65.	#4 14214.
EQUATION	#5 0.	#6 0.	#7 1635.	

OPTION 5
FLU 4685A - AZIMUTH CONTROL UNIT

EQUATION	#1 4544.	#2 28403.	#3 12508.	#4 14214.
EQUATION	#5 0.	#6 0.	#7 2686.	

OPTION 5
FLU 4676B - BOOM FORK ASSEMBLY

EQUATION	#1	#2	#3	#4
	1103.	6455.	7854.	14214.

EQUATION	#5	#6	#7
	0.	0.	467.

OPTION 5
FLU 46854 - TELESCOPE CONTROL UNIT

EQUATION	#1	#2	#3	#4
	8450.	18797.	12171.	14214.

EQUATION	#5	#6	#7
	0.	0.	626.

OPTION 6

OPTION 7

FLUS

WUC	DMDMEAN	XBO	STK	DPIPE	TOTCOND
4676B	0.00	0.00	0.	1.	1.
46766	0.04	0.04	0.	7.	0.
46794	0.05	0.05	0.	5.	0.
46768	0.	0.	0.	0.	416.
4676A	0.	0.	0.	0.	2876.
51921	0.	0.	0.	0.	888.
46857	0.04	0.04	0.	6.	25.
4685A	0.02	0.02	0.	3.	19.
46851	0.	0.	0.	0.	567.
46773	0.	0.	0.	0.	98.
4676H	0.	0.	0.	0.	77.
46771	0.25	0.03	1.	24.	0.
46772	0.09	0.09	0.	17.	10.
46778	0.02	0.02	0.	3.	0.
46854	0.01	0.01	0.	2.	1.

OPTION 8

WUC	PEAK GENS	PEAK OFF-EQUIP GENS	TOTAL GENS	TOTAL OFF-EQUIP GENS
4676B	6.79	0.54	271.62	21.73
46766	43.57	5.66	1742.92	226.58
46794	65.08	8.46	2603.04	338.39
46768	57.72	10.39	2308.80	415.58
4676A	130.72	71.90	5228.76	2875.82
51921	79.23	22.18	3169.01	887.32
46857	50.93	5.09	2037.35	203.74
4685A	39.04	3.12	1561.48	124.92
46851	176.99	14.16	7079.65	566.37
46773	20.37	2.44	814.80	97.78
4676H	23.76	1.90	950.50	76.04
46771	297.03	50.50	11881.19	2019.80
46772	69.61	11.83	2784.22	473.32
46778	36.21	2.90	1448.40	115.87
46854	7.92	0.87	316.92	34.86

OPTION ?

WUC	NOUN
4676B	BOOM FORK ASSEMBLY
46766	RUDDEVATORS
46794	RUDDEVATOR BOOST UNIT
46768	RUDDEVATOR QUADRANT ASSEMBLY
4676A	RUDDEVATOR LOCK ROLLER ASSEMBLY
51921	TRANSMITTER
46857	ELEVATION CONTROL UNIT
4685A	AZIMUTH CONTROL UNIT
46851	SIGNAL COIL AMPLIFIER
46773	SURGE BOOT
4676H	GLAND SEAL
46771	NOZZLE
46772	TAILCONE
46778	EXTENSION DRIVE UNIT
46854	TELESCOPE CONTROL UNIT

APPENDIX F

AARB System

Logistics Support Cost Analysis

This appendix contains the computer output product for the AARB system logistics support cost analysis. It displays all nine output options. The analysis of this appendix appears in Chapter IV.

AARB LOGISTICS SUPPORT COST ANALYSIS

TOTAL LSC = $ 33.35 MILLION.

AVAILABLE OPTIONS

OPTION 1 - TOTAL LSC BROKEN OUT BY EQUATION
OPTION 2 - ALL SYSTEMS RANKED ON COST
OPTION 3 - COST BREAKOUT BY EQUATION FOR A PARTICULAR SYSTEM
OPTION 4 - COST RANKING OF FLUS FOR A PARTICULAR SYSTEM
OPTION 5 - COST BREAKOUT BY EQUATION FOR A PARTICULAR FLU
OPTION 6 - DETAILED SUPPORT EQUIPMENT ANALYSIS
OPTION 7 - DETAILED SPARES ANALYSIS
OPTION 8 - MAINTENANCE GENERATIONS ANALYSIS
OPTION 9 - FLU WORK UNIT CODE/NOUN CROSS-REFERENCE
OPTION 10 - STOP PROGRAM

OPTION 1

EQUATION	#1	#2	#3	#4	#5
	9432050.	6149317.	7131944.	428919.	2160000.

EQUATION	#6	#7	#8
	7403399.	643140.	0.

OPTION 2

SYSTEM	COST(IN MILLIONS)	FRACTION OF TOTAL LSC
467XX	33.35	1.00

OPTION 3
SYSTEM 467XX

EQUATION	#1	#2	#3	#4	#5
	9432050.	6149317.	7131944.	428919.	2160000.

EQUATION	#6	#7	#8
	7403399.	643140.	0.

OPTION 4
SYSTEM 467XX
12 FLUS IN RANKING

	FLU	COST	FRACTION OF SYSTEM COST
1	46755	7258683.	0.22
2	46771	5790092.	0.17
3	51921	2307931.	0.07
4	46794	1214491.	0.04
5	46772	1035157.	0.03
6	46766	611983.	0.02
7	46778	374669.	0.01
8	46765	146356.	0.00
9	46851	126878.	0.00
10	46768	97011.	0.00
11	46773	51752.	0.00
12	4676H	28586.	0.00

CONTRIBUTION OF TOP 12 FLUS = 57 PER CENT OF TOTAL SYSTEM COST.
SYSTEM COST = $ 33.35 MILLION.

OPTION 5
FLU 4676B - ROLLING BOOM PIVOT ASSEMBLY

EQUATION	#1 10000.	#2 5704.	#3 9589.	#4 71305.
EQUATION	#5 0.	#6 0.	#7 413.	

OPTION 5
FLU 46766 - FLIGHT CONTROL SURFACES

EQUATION	#1 75000.	#2 75887.	#3 438262.	#4 14261.
EQUATION	#5 0.	#6 0.	#7 8574.	

OPTION 5
FLU 46794 - SERVO CONTROLS AND ACTUATORS

EQUATION	#1 330000.	#2 253616.	#3 585206.	#4 28522.
EQUATION	#5 0.	#6 0.	#7 17147.	

OPTION 5
FLU 51921 - SENSOR PACKAGE

EQUATION	#1 1505350.	#2 728513.	#3 7371.	#4 14261.
EQUATION	#5 0.	#6 0.	#7 52437.	

OPTION 5
FLU 46851 - SIGNAL COIL AMPLIFIER

EQUATION	#1 33600.	#2 73677.	#3 123.	#4 15350.
EQUATION	#5 0.	#6 0.	#7 4128.	

OPTION 5
FLU 46773 - SURGE BOOT

EQUATION	#1 29000.	#2 5529.	#3 2468.	#4 14261.
EQUATION	#5 0.	#6 0.	#7 494.	

OPTION 5
FLU 4676H - SLIDING GLAND SEAL

EQUATION	#1 2000.	#2 11896.	#3 16.	#4 14261.
EQUATION	#5 0.	#6 0.	#7 413.	

OPTION 5
FLU 46771 - NOZZLE

EQUATION	#1 3015000.	#2 625440.	#3 1986499.	#4 99827.
EQUATION	#5 0.	#6 0.	#7 63326.	

OPTION 5
FLU 46772 - TAILCONE

EQUATION	#1 210000.	#2 24650.	#3 782742.	#4 14261.
EQUATION	#5 0.	#6 0.	#7 3584.	

OPTION 5
FLU 46778 - EXTENSION DRIVE ASSEMBLY

EQUATION	#1 17100.	#2 22933.	#3 290134.	#4 42783.
EQUATION	#5 0.	#6 0.	#7 1720.	

OPTION 5
FLU 46765 - EXTENSION AND RETRACTION SHOCK ABSORBERS

EQUATION	#1 30000.	#2 16362.	#3 69224.	#4 28522.
EQUATION	#5 0.	#6 0.	#7 2248.	

OPTION 5
FLU 46755 - FLY-BY-WIRE CONTROL SYSTEM

EQUATION	#1 4175000.	#2 31272.	#3 2968318.	#4 71305.
EQUATION	#5 0.	#6 0.	#7 28796.	

OPTION 6

OPTION 7

FLUS

WUC	DMDMEAN	XBO	STK	DPIPE	TOTCOND

4676B	0.00	0.00	0.	1.	1.
46766	0.09	0.09	0.	15.	0.
46794	0.18	0.02	1.	30.	0.
51921	0.	0.	0.	0.	4301.
46851	0.	0.	0.	0.	192.
46773	0.	0.	0.	0.	29.
4676H	0.	0.	0.	0.	20.
46771	0.74	0.05	2.	68.	61.
46772	0.05	0.05	0.	9.	5.
46778	0.01	0.01	0.	3.	0.
46765	0.04	0.04	0.	6.	0.
46755	0.48	0.10	1.	98.	33.

OPTION 8

WUC	PEAK GENS	PEAK OFF-EQUIP GENS	TOTAL GENS	TOTAL OFF-EQUIP GENS
4676B	6.00	0.48	240.00	19.20
46766	100.00	13.00	4000.00	520.00
46794	200.00	26.00	8000.00	1040.00
51921	384.00	107.52	15360.00	4300.80
46851	60.00	4.80	2400.00	192.00
46773	6.00	0.72	240.00	28.80
4676H	6.00	0.48	240.00	19.20
46771	300.00	150.00	12000.00	6000.00
46772	35.29	6.00	1411.76	240.00
46778	25.00	2.00	1000.00	80.00
46765	12.00	5.16	480.00	206.40
46755	60.00	54.00	2400.00	2160.00

OPTION 9

WUC	NOUN
4676B	ROLLING BOOM PIVOT ASSEMBLY
46766	FLIGHT CONTROL SURFACES
46794	SERVO CONTROLS AND ACTUATORS
51921	SENSOR PACKAGE
46851	SIGNAL COIL AMPLIFIER
46773	SURGE BOOT
4676H	SLIDING GLAND SEAL
46771	NOZZLE
46772	TAILCONE
46778	EXTENSION DRIVE ASSEMBLY
46765	EXTENSION AND RETRACTION SHOCK ABSORBERS
46755	FLY-BY-WIRE CONTROL SYSTEM

APPENDIX G

Computer Program Output Data Displays

This appendix explains the nine LSC Model computer program output data displays. The same displays apply to the Boom Model developed for this study. The displays present the total weapon system logistics support cost and the system and FLU level logistics support cost contributions.

Option #1--Total LSC Broken Out by Equation

The total weapon system logistics support cost is broken out among the eight equations.

Option #2--All Systems Ranked on Cost

The systems are ranked in order of decreasing logistics support cost. The system identification, its cost, and its percentage of the total logistics support cost are given.

Option #3--Cost Break Out by Equation for a Particular System

The logistics support cost for a given system is broken out among the eight equations.

Option #4--Cost Ranking of FLUs for a Particular System

A specified number of FLUs for a given system are ranked in order of decreasing logistics support cost. The FLU identification, its cost, and its percentage of the system cost are given.

Option #5--Cost Break Out by Equation for a Particular FLU

The logistics support cost for a given FLU is broken out among the eight equations.

Option #6--Detailed Support Equipment Analysis

This option has been inactivated for the Boom Model and is included for continuity only because it is included in the LSC Model computer program. There are no output data displayed, and the computer will query the user for one of the other options.

Option #7--Detailed Spares Analysis

A detailed FLU spares analysis is given showing the required base supply stock, the pipeline, and the base condemnation replacement quantities.

Option #8--Maintenance Generations Analysis

A detailed FLU maintenance generations analysis is given showing both the peak and the total numbers of maintenance generations for both on- and off-equipment maintenance.

Option #9--FLU, WUC/Noun Cross Reference

A FLU, WUC, and noun description cross reference is provided.

APPENDIX H

Comments on Sources of Data Used for the KC-135 Boom Logistics Support Cost Analysis

The purpose of this appendix is to briefly describe the data systems/reports that were used in the KC-135 boom logistics support cost analysis and list the organizations and offices that currently are responsible for them.

In some cases, identical or equivalent information is available from more than one source. Since the choice of the sources is dependent on availability, and to some extent, the personal preferences of the user, only those sources used for the KC-135 boom analysis will be commented upon in this appendix.

The IROS System

The Increase Reliability of Operational Systems (IROS) is a data system that is designed to provide information on system effectiveness--logistics support costs, system downtime, and flight safety data--to weapon system managers. Its objectives are to improve system effectiveness and improve system acquisition by focusing attention on the high cost components in present weapon system (43:2). It is the only Air Force-wide logistics support cost system. The system uses base reported data from the ARM 66-1 Maintenance Data Collection Systems (MDCS) and the AFM 65-110 Equipment Status Reporting System and several depot repair systems (43:2). The data

are generated in the K051 data system quarterly and displayed in a variety of formats.

The D056 Data System

The D056 data system is designed to provide managers with reliability, maintainability and performance information. It is also based primarily on the AFM 66-1 MDCS.

Two D056 reports were used in the KC-135 boom analysis. The D056B5006, "Maintenance Actions, Man-Hours and Aborts by Work Unit Code," report contained MTBF information by WUC. The other D056 report, the D056B5505, "Summarized Maintenance Actions for Selected Work Unit Codes," was a detailed listing of all actions reported against each WUC.

The COSPERANK

COSPERANK is a logistics support cost model based on the D041, Recoverable Consumption Item Requirements, system. The output of this system is a listing of selected D041--depot level--logistics support cost data for recoverable items. The model was developed for use by depot system and item managers. The output is arranged by NSN within each weapon system, for those weapon systems that have been modeled.

The COSPERANK model uses selected, auditable depot data to arrive at a yearly depot support cost. The model then estimates a similar base support cost. These costs could be calculated by knowing the algorithms using the D041 data--which is also available.

The COSPERANK was developed at Oklahoma City Air Logistics Center/MMPMC and, as yet, has not gained complete Air Force acceptance. Since it was a concise and useful system, and the system was available to the researchers, it was used in the analysis.

Two other data reports, the D049, "Full Range List," and the G033BQI3B, "Aerospace Vehicle Inventory by Station (Within M/D/S)," were also used. Both were discussed in the text on pages 64 and 77, respectively.

Table XVIII on page 221 lists the data systems and reports used in the KC-135 logistics support cost analysis. The organizations and office symbols were current at the time this report was written.

Table XVIII
Data Sources Used for the KC-135 Variable Values

DATA REPORT NUMBER	TITLE OF DATA REPORT	VALUES OF VARIABLES OR INFORMATION	SOURCE OF DATA PRODUCT	FREQUENCY	TYPE OF PRODUCT
K051.PN3L	Logistics Support Cost Ranking Work Unit Code Status	Contribution by WUC	AFLC/MMOMA	Quarterly	Microfiche
K051.PN7L	Maintenance Action Summary	IMH, RMH, BMC	AFLC/MMOMA	Quarterly	Microfiche
K051.PN8L	Logistics Support Cost File Maintenance Record	W, Partial NSN/ WUC Cross Reference	AFLC/MMOMA	Quarterly	Microfiche
D056B5006	Maintenance Actions, Man-Hours, and Aborts by Work Unit Codes	MTBF, SHQ	AFLC/MMOMA	Monthly	Microfiche
D056B5505	Summarized Maintenance Actions for Selected Work Unit Codes	BMH, RIP	AFLC/MMOMA	On Demand	Computer Printout
COSPERANK	D041 Data "Fetch"	COND, DMX, NRTS, RTS, UC	OCALA/MMPMC[1]	On Demand	Computer Printout
G033BQI3B	Aerospace Vehicle Inventory by Station (Within M/D/S)	M, OS	AFLC/MMR	Monthly	Bound Document
D049	Full Range List	PN/Noun/NSN Cross Reference	XXALC/MMYT[2]	On Demand	Computer Printout

[1]Oklahoma City Air Logistics Center (OCALC)
[2]XXALC means appropriate ALC for weapon system and MMYT means Technical Services at appropriate ALC.

Vitae

Richard T. Jeffreys was born 12 September 1946 in Ann Arbor, Michigan. He grew up in Ann Arbor, graduating from Ann Arbor High School, Ann Arbor, Michigan, in 1964. Upon graduation from the University of Michigan in December 1968 with a Bachelor of Science in Electrical Engineering and as an AFROTC Distinguished Graduate, he received a commission in the United States Air Force. He completed pilot training and received his wings in December 1969. He served as a C-130 pilot with the 773rd Tactical Airlift Squadron, Clark AB, Philippines; and as an HC-130 aircraft commander with the 41st Aerospace Rescue and Recovery Squadron, Hamilton AFB, California. He then served as the Chief of Flying Safety with the 9th Weather Reconnaissance Wing, McClellan AFB, California. He entered the Graduate Systems Management program of the Air Force Institute of Technology in June 1975.

Carver L. Sears graduated from high school at Ventura, California, in 1960. He attended the United States Air Force Academy where he graduated in 1964 with a Bachelor of Science in Basic Sciences. He has flown KC-135 tankers for six years and C-130 tactical transports for two years. Besides flying he has had experience as an Airlift Command Center controller and as a scheduler of SAC B-52 and KC-135 aircrews. He entered the Graduate Systems Management program of the Air Force Institute of Technology in June 1975.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Under an Air Force contract, Douglas Aircraft Company is developing an Advanced Aerial Refueling Boom (AARB) for the Advanced Tanker/Cargo Aircraft System Program Office (ATCA SPO). The purpose of the AARB development program is to demonstrate that an advanced technology boom system, which will eliminate some of the limitations of the existing KC-135 boom, can be designed and successfully flown. To date, development of the AARB has been → next page

cont. 20.

mainly oriented toward performance--meeting the design requirements. The ATCA SPO now desires to examine the costs of supporting the proposed design, if it is produced.

This thesis is directed toward identifying the differential logistics support costs of the AARB. The Boom Model, a tailored version of the Air Force Logistics Command Logistics Support Cost (LSC) Model, is used to develop the logistics support cost figure of merit for the proposed AARB. The Boom Model is also used to develop a similar figure of merit for the existing KC-135 boom. The values for variables used in the KC-135 boom analysis are obtained from existing Air Force maintenance data collection systems. A methodology for extracting data from these systems is given. Because of the uncertainties associated with early, initial estimates for the AARB, sensitivity analyses are performed on selected variables. Conclusions and recommendations pertaining to both the AARB and KC-135 boom analyses and the LSC Model are given.